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# COMPUTER PROGRAM APPLICATIONS TO TACTICAL CONCEPTUAL DESIGN

Martin David Sullivan

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# NAVAL POSTGRADUATE SCHOOL
Monterey, California

# THESIS

# COMPUTER PROGRAM APPLICATIONS TO TACTICAL MISSILE CONCEPTUAL DESIGN

by

Martin David Sullivan

June 1981

Thesis Advisor: Gerald H. Lindsey

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| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>Computer Program Applications to Tactical Missile Conceptual Design | | 5. TYPE OF REPORT & PERIOD COVERED<br>Master's Thesis<br>June 1981 |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>Martin David Sullivan | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Naval Postgraduate School<br>Monterey, California 93940 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Naval Postgraduate School<br>Monterey, California 93940 | | 12. REPORT DATE<br>June 1981 |
| | | 13. NUMBER OF PAGES<br>199 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report) |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |
| 16. DISTRIBUTION STATEMENT (of this Report)<br>Approved for public release; distribution unlimited | | |
| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) | | |
| 18. SUPPLEMENTARY NOTES | | |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Computer programs for warhead design, missile guidance, propulsion and aerodynamic coefficients. | | |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This thesis is comprised of four independent computer programs and their related operating instructions. Each of these programs focuses on a particular facet of tactical missile design. The topics covered include guidance and trajectory calculations, rocket motor propulsion sizing, warhead design, and aerodynamic coefficient determination. The programs are developed from accepted mathematical procedures and are tailored to optimize operator interaction for educational purposes. This thesis is intended to be utilized | | |

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(Page 1) S/N 0102-014-6601

Block 20 continued.
as a supplement to the thesis Tactical Missile Conceptual Design by D. R. Redmon, Naval Postgraduate School, September 1980.

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# Computer Program Applications to Tactical Missile Conceptual Design

by

Martin David Sullivan
Lieutenant, United States Navy
B.S., Georgia Institute of Technology, 1975

Submitted in partial fullfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
June 1981

# ABSTRACT

This thesis is comprised of four independent computer programs and their related operating instructions. Each of these programs focuses on a particular facet of tactical missile design. The topics covered include guidance and trajectory calculations, rocket motor propulsion sizing, warhead design, and aerodynamic coefficient determination. The programs are developed from accepted mathematical procedures and are tailored to optimize operator interaction for educational purposes. This thesis is intended to be utilized as a supplement to the thesis Tactical Missile Conceptual Design by D.R.Redmon, Naval Postgraduate School, September 1980.

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## ACKNOWLEDGEMENTS

I am deeply obligated to Professor Gerald H. Lindsey both for his faith in my abilities and for his guidance in the preparation of this thesis. He allowed me to work freely in an area of great interest to me and provided the proper direction and assistance to help me understand the obvious.

The greatest appreciation must be given to my wife, Kathleen, who has learned to live without her husband quite bravely during the preparation of this thesis. Her support, understanding, and love have been incomparable and indispensible during this trying period.

Finally, a certain acknowledgement must be provided to the staff of the Naval Postgraduate School Computer Center who, in the process of installing and debugging a whole new computer system, have made this thesis a most exciting and memorable undertaking.

# I. INTRODUCTION

The programs contained in this thesis were assembled expressly to supplement the work of Dan Redmon in his thesis, Tactical Missile Conceptual Design. Two of the programs, LPATH, the trajectory model, and LAERO1, the aerodynamic coefficients program, originated in Redmon's thesis and were expanded/modified for use on the Naval Postgraduate School's new IBM 370 computer system. The other two programs were generated for this thesis and utilize the procedures and principles outlined by Redmon.

The specific intention of these programs is to provide students of tactical missile engineering and design with a method of solving complex mathematical routines rapidly and interactively. Each of the programs request data which are likely to be used as design parameters for the topics concerned. The programs also allow repeated operation with input alteration capability, allowing the user to personally optimize his design. This approach was chosen to allow students to understand the relationships various input parameters have with the final solutions.

# II. TRAJECTORY MODELS

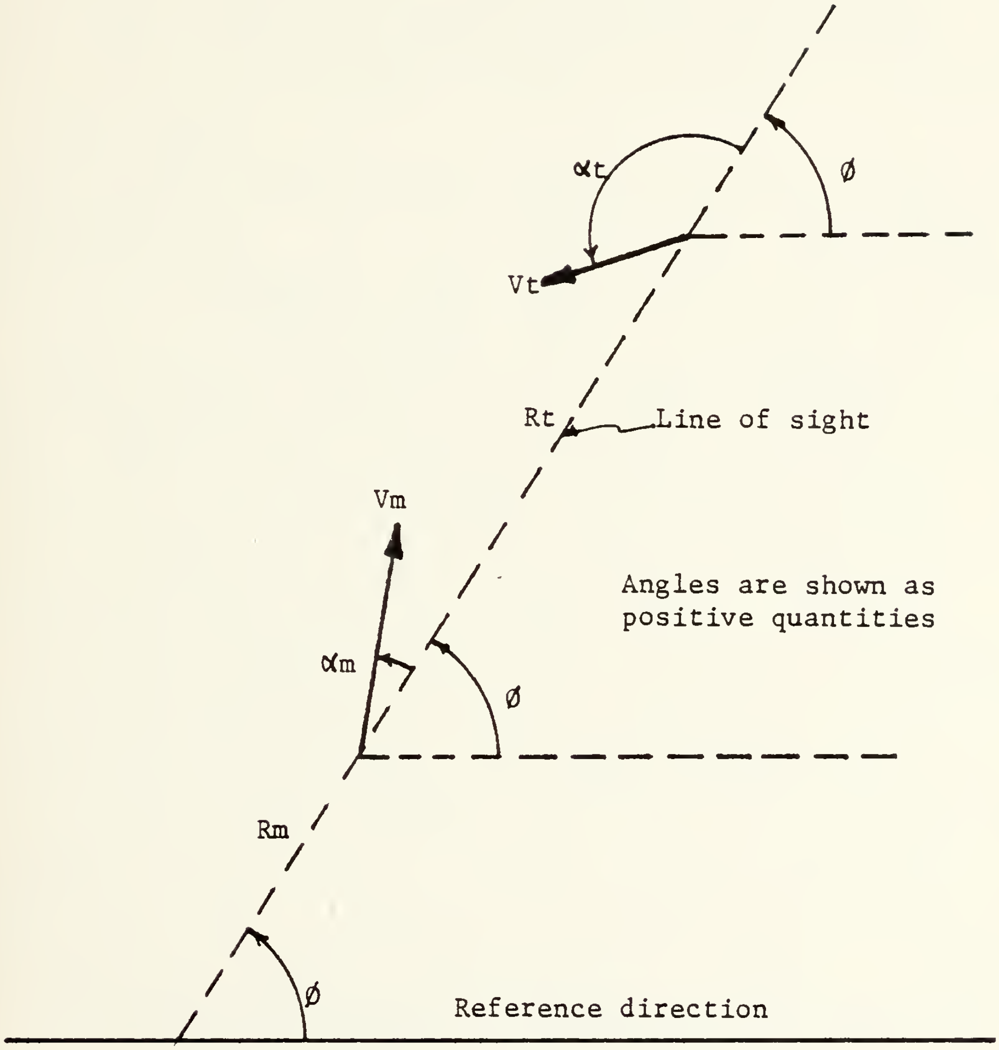
## A. DESCRIPTION AND ORIGIN OF PROGRAM

This program applies the principles of missile guidance laws to the terminal phase (the last 5 to 10 seconds) of a missile trajectory in order to determine the maximum normal acceleration on the missile for a given scenario. Of the three general guidance law categories, pursuit guidance is not included in the program capability. It has been found that pursuit guidance invariably produces a tail-chase situation, greatly reducing an anti-air missile's effectiveness against maneuvering targets of similar speed characteristics. Line-of-sight guidance and proportional navigation guidance are both options of the program.

Figure (II-1) shows a typical encounter geometry as required for this program. The encounter is considered to occur entirely within a two- dimensional plane. No differentiation is required or assumed concerning the orientation of the encounter plane. The plane may be at any angle to the horizontal as desired by the program user. The reference direction is an arbitrary choice by the program user. The angles shown are positive in value, however the program does not require positive angles. If TAL were 150 degrees, it could also be entered as -210 degrees. The IRA term represents the initial range to the target.

Tangential velocities (air speeds) of the missile and the target are considered by the program to be constant throughout the problem. Since the program concerns itself with only the final moments of a trajectory, this is a reasonable consideration. Target normal accelerations, when specified by the user, are also held constant throughout the problem for the same reason. The missile normal

Program Variables
Ø=LOS (line of sight angle)
αt=TAL (target alpha)
αm=MAL (missile alpha)
Vt=TSP (target speed)
Vm=MSP (missile speed)
Rt=IRT (initial range to target from missile launch point)
Rm=IRM (initial range to missile from launch point)



Angles are shown as positive quantities

Figure (II-1). Encounter geometry

acceleration, however, is a function of the guidance laws and will vary according to the resulting flight path requirements. A constraint on the encounter is that the missile normal acceleration must be zero at the start of the problem.

The program "flies" both the missile and the target as simple points in space with no consideration given to aerodynamics. The missile will always strike the target dead center when it is given the proper speed advantage for the encounter since there is no provision for statistical miss analysis. The unbounded nature of the missile normal acceleration allows the missile to turn as rapidly as necessary to hit the target.

This program analyzes the given encounter by time increment calculations. As is the case with all integrations conducted by incremental steps, the accuracy of the results is a function of the increment size. The results will become increasingly accurate as the time increment is made smaller. However, as the time increment decreases in size, the length of the output becomes increasingly longer. The user must balance the desire for accuracy against the amount of time he wishes to spend on the computer terminal.

The primary output is a tabular listing of the missile and target coordinates at each time increment. The coordinate frame is established within the encounter plane with the abscissa oriented along the reference direction. The problem stops once the missile has passed its closest point of approach to the target. Output then provides the time to intercept from time of problem initiation and the maximum acceleration the missile was required to endure. A Versatec plot of overlaying successive encounters is an optional output.

This program originated as two seperate BASIC programs written by Redmon [Ref. 1] for use on the HP 9830 desktop calculator. It was subsequently translated into FORTRAN IV for use on the IBM 370 computer system.

B. USER INSTRUCTIONS

If it is desired to abort the operation of this program prematurely, two methods are available. When the program is waiting for data entry, press ENTER. When the program is not waiting for data entry but is processing, type "HX" and press ENTER. Both actions will return the terminal to CMS mode.

When the screen becomes full, or "MORE...." appears in the status area, clear the screen by pressing ALT and CLEAR simultaneously. At several points in the program, the user will be directed to "CLEAR SCREEN AND INPUT 0". This is to provide proper positioning of the output on the screen for ease of reading. If any other symbol than "4 A ▨" should appear in the lower left of the screen, press RESET and continue.

1. Turn the terminal on with the red I O switch.

2. When the large "NPS" appears after about 30 seconds, press RESET, then press ENTER.

3. When "CP READ" appears in the status area on the lower right of the screen, type "L nnnnP", where nnnn is your 4-digit user number, then press ENTER.

4. You will now be asked for your password. Type it in (the characters will not appear on the screen), then press ENTER.

5. Your personal file must contain a PROFILE EXEC routine with the appropriate Fortran GLOBAL statement. If it does not, type "GLOBAL TXTLIB FORTMOD2 MOD2EEH", then press ENTER.

6. Type "LINK TO xxxxP 191 AS 192 RR", where xxxx is the 4-digit user number for the project file, then press ENTER.

7. You will now be asked for the project file password. Type it in (the characters will not appear on the screen), then press ENTER.

8. Type "ACCESS 192 B" and press ENTER.

9. Press ALT and CLEAR simultaneously to clear screen.

10. Type "LPATH" and press ENTER.

11. Input the following data as it is requested on the screen by typing the data and then pressing ENTER. Ensure that the data is input as either decimal or integer as specified. The terms in parenthesis below are the program variable names.

| Parameter | Units | Value range |
|---|---|---|
| Trajectory option (TITLE) | none | 0=Line-of-sight<br>1=Proportional navigation<br>2=Both |
| Time increment (DEL) | seconds | Larger than .0001 times the problem time |
| Navigation constant (NAV) | none | 2.5 to 6.5 |
| LOS Angle (LOS) | degrees | 0.0 to 360.0 |
| Initial target range from the launch site (IRT) | meters | Larger than the missile range |
| Target speed (TSP) | m/sec | Larger than 0.0 |
| Target normal acceleration (TAC) | m/sec/sec | Positive is to target's left |
| Initial target angle to line of sight (TAL) | degrees | 0.0 to 360.0 the |
| Missile speed (MSP) | m/sec | Larger than 0.0 |
| Initial missile range from launch site (IRM) | meters | Such that impact occurs in less than 10 seconds |

12. If you desire to rerun the problem, or want to run a new problem, answer the questions appropriately when asked by the terminal after the execution of the current problem.

13. To receive the printout and plot of your encounters, answer "no" to rerunning or restarting the problem when asked by the terminal and follow the directions presented on the screen.

14. Upon completion of the program, type "LOGOFF" and press ENTER.

15. Turn the terminal off with the red switch.

C. EXAMPLE PROBLEMS

1. Example II-A. Line-of-sight Non-maneuvering Crossing Target

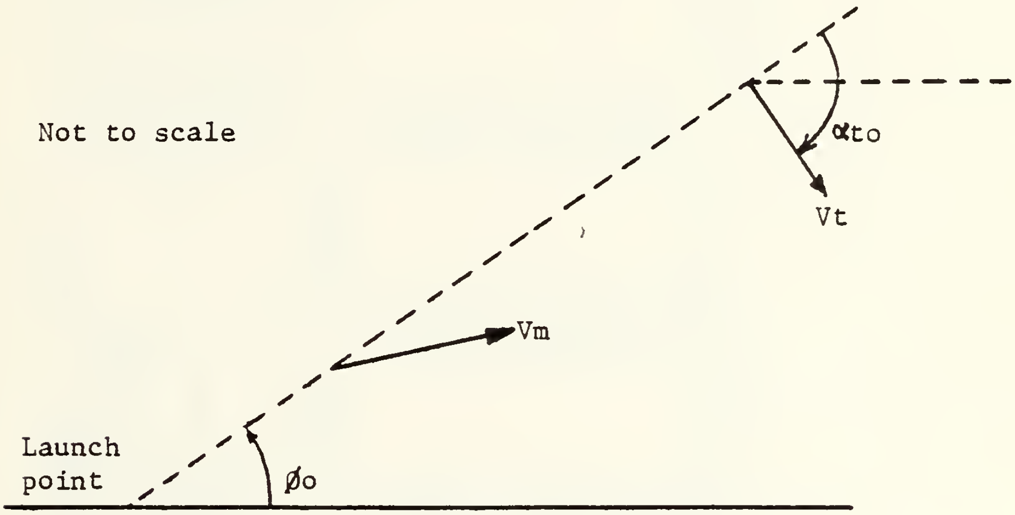


Figure (II-2). Non-maneuvering crossing target

Rt=10000 meters
Rm=9000 meters
Øo=30.0 degrees
αto=-90.0 degrees
at=0
Vt=200 meters/second
Vm=800 meters/second

TABLE (II-1). OUTPUT OF EXAMPLE II-A

```
$$$$ RUN NUMBER  1
                         PROBLEM PARAMETERS
                 01) TIME INCREMENT                0.0050 SECONDS
                 02) NAVIGATION CONSTANT           0.0
                 03) LINE-OF-SIGHT ANGLE          30.000  DEGREES
                 04) INITIAL SEPARATION         1000.000  METERS
                 05) TARGET SPEED                200.000  METERS/SEC
                 06) TA GET ACCELERATION           0.0    M/SEC/SEC
                 07) TARGET ALPHA                -90.000  DEGREES
                 08) MISSILE SPEED               800.000  METERS/SEC
                 09) MISSILE INITIAL ALPHA       -13.003  DEGREES

                LINE OF SIGHT GUIDANCE INTERCEPT TRAJECTORY
PROBLEM          --POSITION COORDINATES (METERS)--       RANGE      ACCEL.
TIME(S)            XM        YM        XT        YT      (METERS)   (M/S/S)
 0.0               0.0       0.0     866.0     500.0       0.0        0.0
 0.125            95.7      29.0     878.5     478.3     902.6     -31.982
 0.250           191.6      57.5     891.0     456.7     805.4     -31.962
 0.375           287.5      85.5     903.5     435.0     708.2     -31.942
 0.500           383.7     113.1     916.0     413.4     611.2     -31.921
 0.625           479.9     140.1     928.5     391.7     514.3     -31.899
 0.750           576.3     166.7     941.0     370.1     417.5     -31.876
 0.875           672.9     192.8     953.5     348.4     320.9     -31.852
 1.000           769.5     218.4     966.0     326.8     224.3     -31.828
 1.125           866.3     243.6     978.5     305.1     127.9     -31.803
 1.250           963.2     268.3     991.0     283.4      31.7     -31.777
 1.290           994.3     276.0     995.0     276.5       0.9     -31.768
                   MAXIMUM LATERAL ACCELERATION ON THE MISSILE
                   IS    -32.000 M/SEC/SEC, OR     -3.26 G"S.
                   THE TIME TO INTERCEPT IS  1.295 SECONDS.
```

Figure (II-3). Versatec plot of example II-A

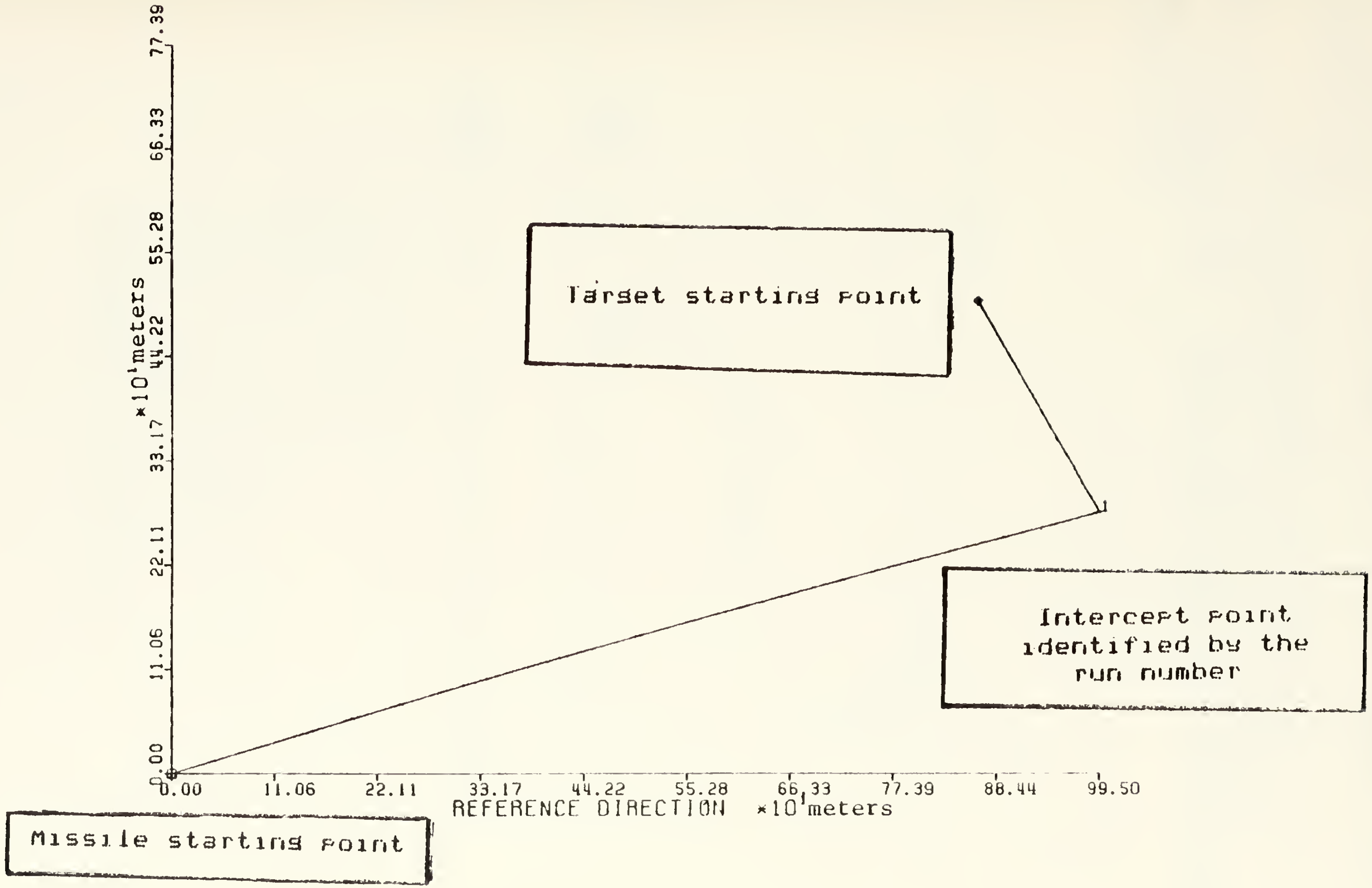


Table (II-1) is the corresponding computer output for this encounter. As indicated, the missile maximum normal acceleration is

am= -32.00 m/sec/sec or -3.26 g's.

Figure (II-3) is the Versatec plot of the engagement.

2. Example II-B. Proportional Navigation Maneuvering Crossing Target

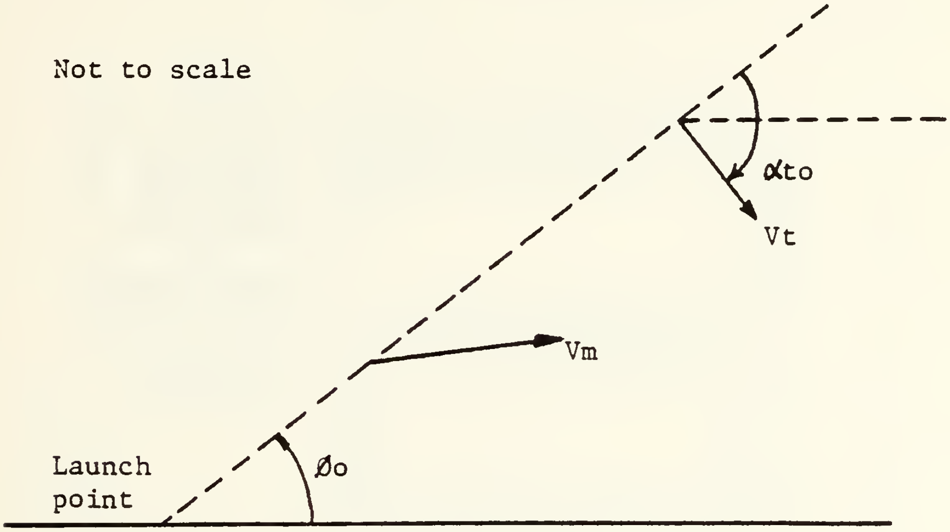


Figure (II-4). Maneuvering crossing target

Rt=10000 meters
Rm=9000 meters
Øo=30.0 degrees
αto=-90.0 degrees
at=156.8 m/sec/sec (16 g's)
Vt=200 meters/second
Vm=800 meters/second
Navigation constant=3.06

TABLE (II-2). OUTPUT OF EXAMPLE II-B

```
$$$$ RUN NUMBER   1
                        PROBLEM PARAMETERS
            01) TIME INCREMENT               0.0050 SECONDS
            02) NAVIGATION CONSTANT          3.060
            03) LINE-OF-SIGHT ANGLE         30.000 DEGREES
            04) INITIAL SEPARATION        1000.000 METERS
            05) TARGET SPEED               200.000 METERS/SEC
            06) TA GET ACCELERATION        156.800 M/SEC/SEC
            07) TARGET ALPHA               -90.000 DEGREES
            08) MISSILE SPEED              800.000 METERS/SEC
            09) MISSILE INITIAL ALPHA      -14.478 DEGREES

     PROPORTIONAL NAVIGATION GUIDANCE INTERCEPT TRAJECTORY
PROBLEM     --POSITION COORDINATES (METERS)--       RANGE     ACCEL.
TIME(S)       XM        YM        XT        YT     (METERS)  (M/S/S)
 0.0          0.0       0.0     866.0     500.0    1000.0       0.0
 0.125       96.4      26.8     879.5     479.0     904.3       2.326
 0.250      192.7      53.6     895.0     459.4     811.1       9.733
 0.375      289.0      80.5     912.3     441.4     720.3      22.483
 0.500      385.2     107.8     931.4     425.1     631.7      40.670
 0.625      481.2     135.7     951.9     410.9     545.2      64.170
 0.750      577.0     164.6     973.7     398.6     460.6      92.587
 0.875      672.3     194.8     996.6     388.6     377.8     125.188
 1.000      767.0     226.9    1020.3     380.9     296.5     160.838
 1.125      860.8     261.4    1044.7     375.5     216.4     197.903
 1.250      953.6     298.8    1069.5     372.6     137.5     234.093
 1.375     1044.9     339.5    1094.5     372.1      59.4     266.065
 1.470     1113.2     372.9    1113.5     373.3       0.5     283.935
             MAXIMUM LATERAL ACCELERATION ON THE MISSILE
             IS    283.935 M/SEC/SEC, OR     28.95 G"S.
             THE TIME TO INTERCEPT IS  1.475 SECONDS.
```

Figure (II-5). Versatec plot of example II-B

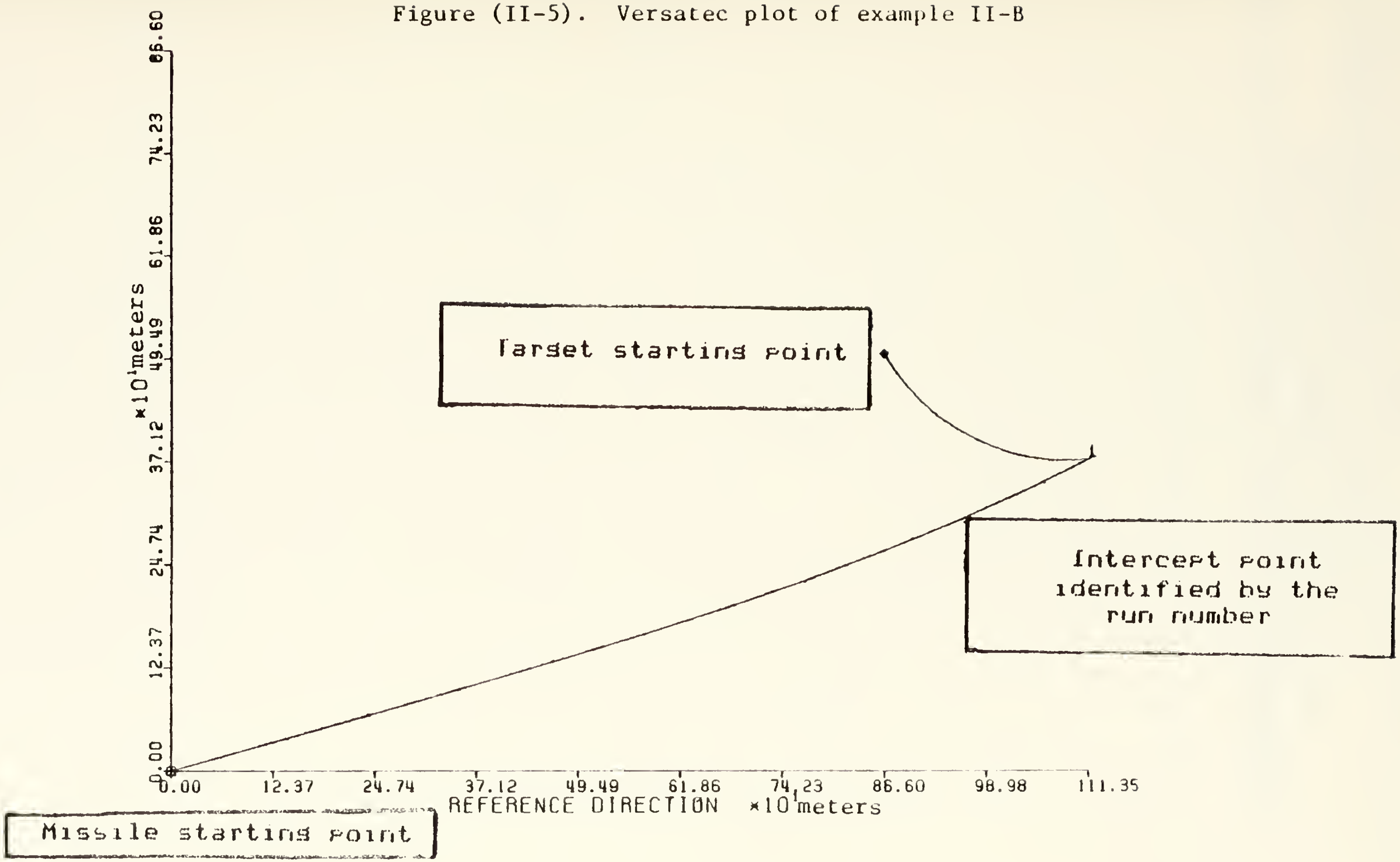
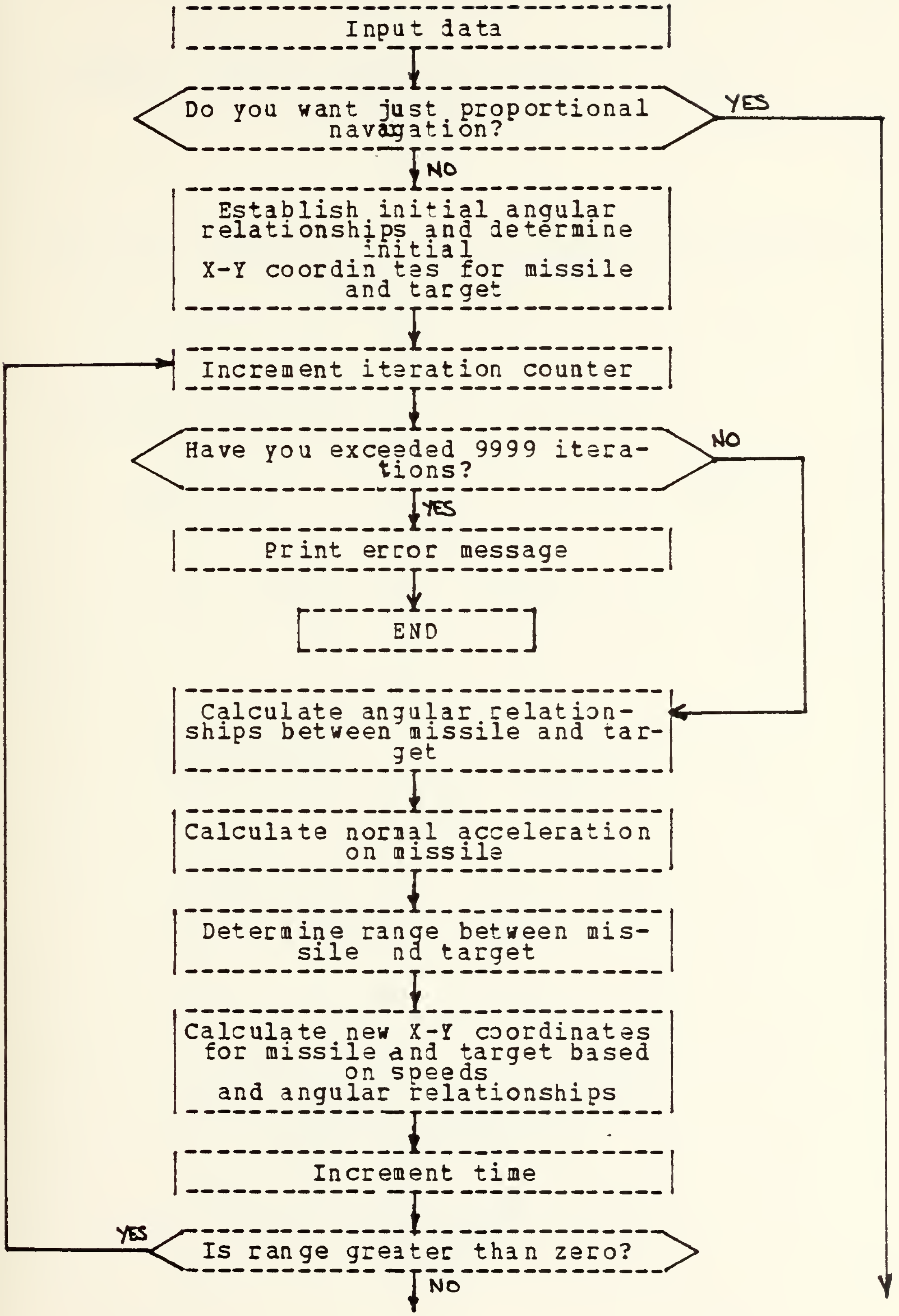


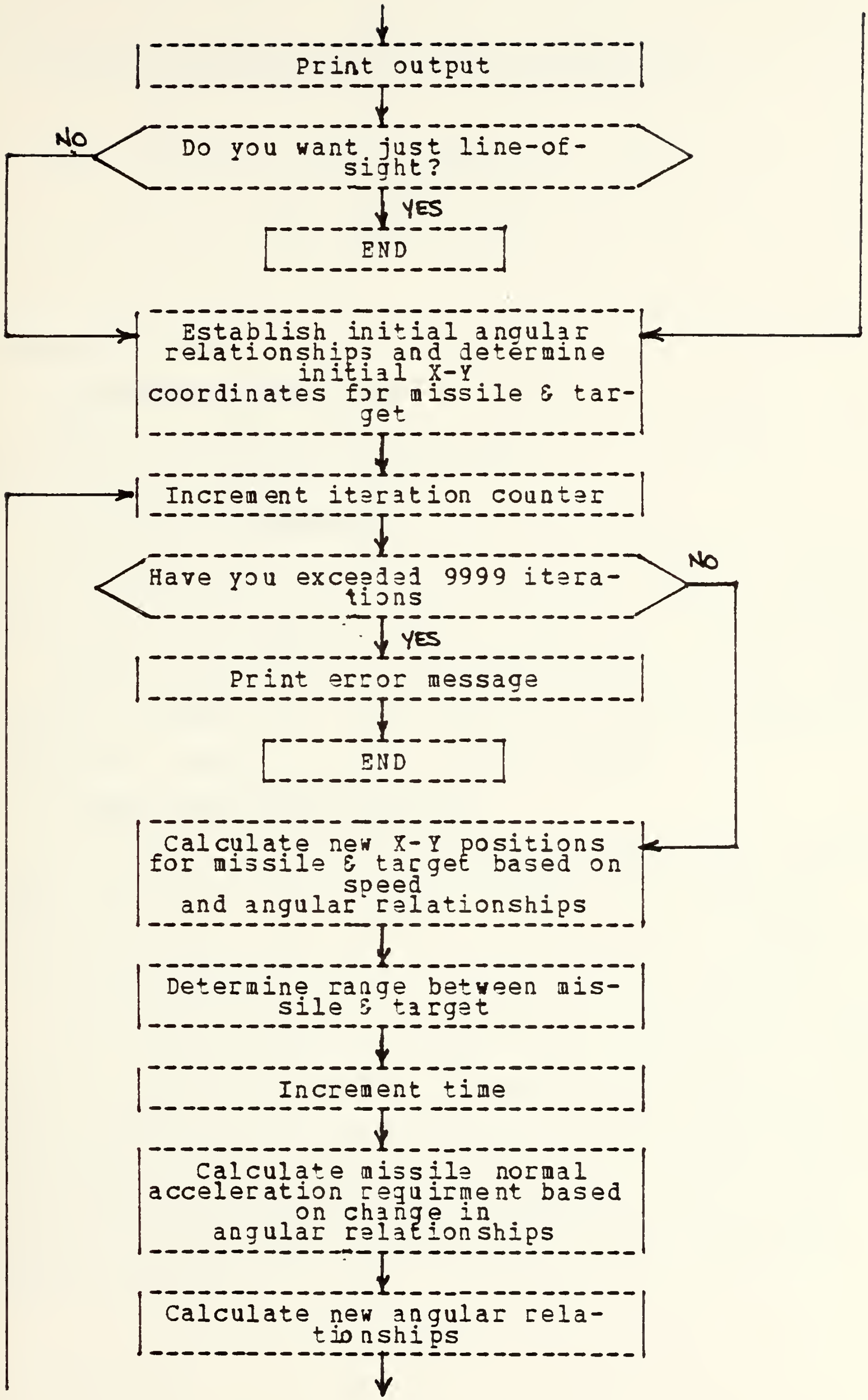
Table (II-2) is the computer output for this encounter. The missile maximum normal acceleration is

am= 283.94 m/sec/sec or 28.95 g's.

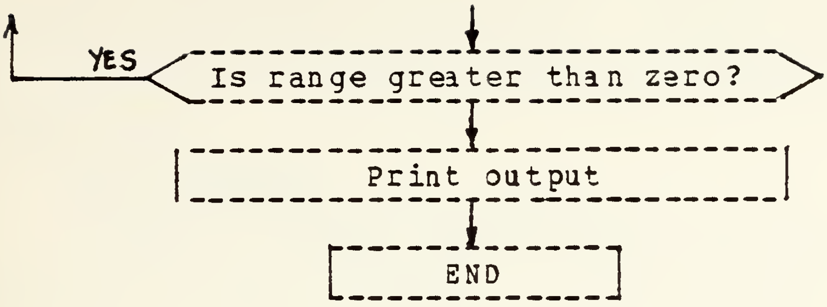
Figure (II-5) is the Versatec plot of the engagement.

## D. PROCEDURAL FLOWCHART


Input data
Do you want just proportional navagation?
YES
NO
Establish initial angular relationships and determine initial X-Y coordinates for missile and target
Increment iteration counter
Have you exceeded 9999 iterations?
NO
YES
Print error message
END
Calculate angular relationships between missile and target
Calculate normal acceleration on missile
Determine range between missile and target
Calculate new X-Y coordinates for missile and target based on speeds and angular relationships
Increment time
YES
Is range greater than zero?
NO



Print output
Do you want just line-of-sight?
NO
YES
END
Establish initial angular relationships and determine initial X-Y coordinates for missile & target
Increment iteration counter
Have you exceeded 9999 iterations
NO
YES
Print error message
END
Calculate new X-Y positions for missile & target based on speed and angular relationships
Determine range between missile & target
Increment time
Calculate missile normal acceleration requirment based on change in angular relationships
Calculate new angular relationships



## E. PROGRAM CHANGES

### 1. Language Translation.

The two BASIC programs contained in Reference 1 were translated into standard FORTRAN IV.

### 2. Program Condensation.

The two individual programs were combined to form a single integrated routine which allows the user to choose either of the two guidance laws or both for a given encounter. The two original programs were meshed such that only the actual guidance law algorithms are separate routines, all input and output routines are now common.

### 3. Input and Output Facility.

The data input instructions were modified to maximize user facility on the IBM 370 System 3278 terminals. Completion of data input is now followed by data feedback for user verification prior to actual program execution.

Data output has been expanded to provide data delivery to three destinations; to the user's terminal for observation, to a printer file for hardcopy duplication of the terminal display, and to a plot data file for subsequent use by the plot program. The destinations are options chosen by the user for each execution of the program. Up to nine different problems can be printed and plotted each time the program is entered.

The program can now be rerun multiple times without exiting and re-entering each time. The user has a choice of either rerunning the same problem or initiating a new problem completely.

4. Plot Program.

PATHPLOT FORTRAN was developed to produce a Versatec plot picture of the encounter. It will produce a single plot each time the program is entered and will plot up to 9 engagements in an overlaying manner. This format was adopted to allow comparisons of successive input data modifications.

5. Data Overcapacity Check.

If the user initiates a problem requiring more than 9999 iterations, the program will stop. The user will be notified of the error and given the opportunity to rerun the problem.

6. Initial Missile Acceleration.

Initial missile acceleration was removed as a user input variable and established as zero. Due to the mathematical nature (i.e., no physical constraints) of the program, any "wrong" accelerations of the missile in the initial state were immediately "corrected" by the algorithm. The model is better served by providing no initial accelerations.

7. Theta Angles.

Both the target and the missile theta angles (the angles between the velocity vectors and the reference direction) were removed as user input variables. The program now calculates the theta angles from other input data, reducing redundancy and possible contradiction of input data.

8. Initial Conditions Perspective.

Originally, the missile guidance calculations started at t=0. Specifically, the anchor point for the line

of sight solution was the point where the missile commenced the problem, whether or not that was on the launch site. This produced a situation removed from reality where the LOS anchor point should be at the fire control location, usually at or near the launch site. A similar, though less pronounced, condition existed for the proportional navigation solution. The program was modified to provide proper positioning of the external guidance reference. As a result of the modification, an additional output is the correct lead angle for the missile at the start of the problem. This angle is based on the assumption that neither the target nor the missile have maneuvered prior to time $t=0$.

# III. WARHEAD DESIGN

## A. DESCRIPTION AND ORIGIN

This program develops a warhead using the same methods as presented by D Redmon [Ref. 1]. However, its capability is somewhat greater and it applies the relationships in a slightly different manner. This program was written for this thesis in FORTRAN IV for use on the IBM 370 computer system 3278 terminals. It is configured expressly for operator-computer interaction.

It starts with an initial input of data from which a table of fragment initial velocities is generated and presented to the user. From this, the user selects values for fragment mass and impact velocity and another table is generated and displayed. From this one, the desired probability of hit given a detonation is selected and the final solution is produced. At various points during the operation of the program, the user will have opportunities to alter or revise selected parameters.

The program is limited to a cylindrical warhead with either a solid or hollow core. The fragments are required to be square in shape and are sized by the program. Figure (III-1) illustrates the shape of the warhead and the location of various input and output quantities.

Initially, the target altitude is used to determine the atmospheric density, temperature and speed of sound. These values are, in turn, used to calculate required initial velocities for the fragments. The program is preloaded with various values for the fragment mass and impact velocity, which are used to generate the table of initial velocities. These velocities come from the following relationship:

$$V(hit)=Vi[\exp(-ks)]$$

$$k=\frac{1}{2m}\rho_a A C_d$$

where V(hit) is the impact velocity, Vi is the initial velocity, s is the kill radius, m is the fragment mass, $\rho_a$ is the atmospheric density, A is the plan area of the fragment, and Cd is the drag coefficient of the fragment.

The ballistic limit velocity is calculated for the various presized fragments and is provided as a reference when choosing an appropriate impact velocity. The ballistic limit velocity is that velocity at which one half of the fragments will penetrate the target's skin and the other half will not. The empirical relationship, developed by A. E. Fuhs [Ref. 6], presents the ballistic limit velocity as a function of the fragment size to skin thickness ratio. His function dealt with steel fragments impacting an aluminum plate. His results were modified to qualitatively account for different skin materials and fragment densities.

Next computed is the fragment spray angle and the critical miss distance. The spray angle is a function of the initial velocity, the detonation velocity and the warhead length. The critical miss distance is defined as the range where the fragment spray exactly covers the entire target. The critical miss distance is used by the program to separate the two functions which determine the average number of hits received by the target. The program assumes the target is always centered within the fragment spray and aligned perpendicular to the central ray of the spray.

A selection of warheads is then produced, one for each of a preloaded set of Pd's (probability of a hit given a detonation) to provide the user with a Pd versus warhead weight/size trade off comparison. This sizing process is based entirely on the following relationship:

$$Pd=1-\exp(-a)$$

where a is the average number of hits. The variable a, as shown by Redmon [Ref. 1], is a function of the cube of the warhead radius. The user then chooses a desired Pd which, in turn, produces the final warhead sizing.

Values that are shown in tabular form for user selection and input into the program are not limited to those displayed. Any value in between the displayed values or completely outside of the value range may be used. The one exception is that Pd can never be selected to be larger than .999 and may even, if forced by the program limitations, be required to be lower. Since ultimately in this algorithm, Pd is a function of the warhead radius, the maximum value for Pd may be reduced in order to keep the radius within the original input parameters. The user is notified if this condition occurs.

Useful reference information for some common explosives and case materials is contained in the following tables.

Table (III-1). Characteristics of common explosives

| Explosive | Density (lb/cu.in) | 2E(ft/sec) | Vd (ft/sec) |
|---|---|---|---|
| TNT | .0574 | 7600. | 21785. |
| RDX | .0596 | 9300. | 26837. |
| HMX | .0665 | 10230. | 29934. |
| PETN | .0625 | 9300. | 27231. |
| TETRYL | .0585 | 8200. | 25755. |
| COMP B | .0607 | 8800. | 25722. |
| OCTOL | .0650 | 9500. | 28356. |

Table (III-2). Densities of common case materials

| Case material | Density (lb/cu.in) |
|---|---|
| Steel | .283 |
| Aluminum | .100 |
| Uranium | .688 |
| Titanium | .163 |
| Lead | .410 |

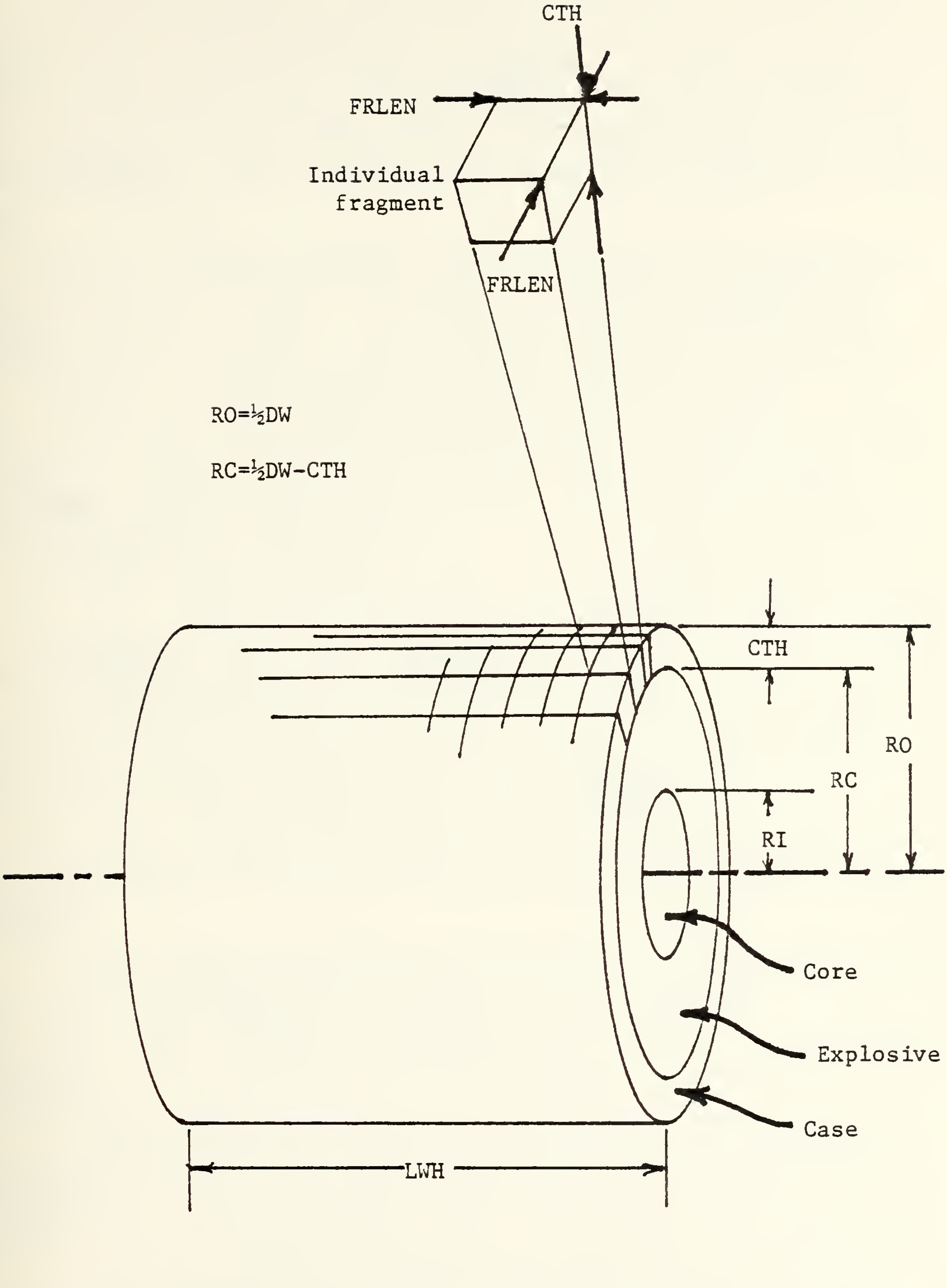


Figure (III-1). Form of warhead as used by the program

## B. USER INSTRUCTIONS

If it is desired to abort the operation of this program prematurely, two methods are available. When the program is waiting for data entry, press ENTER. When the program is not waiting for data entry but is processing, type "HX" and press ENTER. Both actions will return the terminal to CMS mode.

When the screen becomes full, or "MORE...." appears in the status area, clear the screen by pressing ALT and CLEAR simultaneously. At several points in the program, the user will be directed to "CLEAR SCREEN AND INPUT 0". This is to provide proper positioning of the output on the screen for ease of reading. If any other symbol than "4 A ▨" should appear in the lower left of the screen, press RESET and continue.

1. Turn the terminal on with the red I O switch.

2. When the large "NPS" appears after about 30 seconds, press RESET, then press ENTER.

3. When "CP READ" appears in the status area on the lower right of the screen, type "L nnnnP", where nnnn is your 4-digit user number, then press ENTER.

4. You will now be asked for your password. Type it in (the characters will not appear on the screen), then press ENTER.

5. Your personal file must contain a PROFILE EXEC routine with the appropriate Fortran GLOBAL statement. If it does not, type "GLOBAL TXTLIB FORTMOD2 MOD2EEH", then press ENTER.

6. Type "LINK TO xxxxP 191 AS 192 RR", where xxxx is the 4-digit user number for the project file, then press ENTER.

7. You will now be asked for the project file password. Type it in (the characters will not appear on the screen), then press ENTER.

8. Type "ACCESS 192 B" and press ENTER.

9. Press ALT and CLEAR simultaneously to clear screen.

10. Type "LBOMB" and press ENTER.

11. Input the following data as it is requested on the screen by typing the data and then pressing ENTER. Ensure that the data is input as either decimal or integer as specified. The terms in parenthesis are the program variable names. Input the following variables as decimal values:

| | |
|---|---|
| Explosive density (XDEN) | lb/cu.in |
| Explosive Gurney constant (GC) | ft/sec |
| Explosive detonation velocity (VD) | ft/sec |
| Case material density (CDEN) | lb/cu.ft |
| Desired kill radius (RKILL) | feet |
| Warhead diameter (DW) | inches |
| Warhead length-to-diameter ratio (LTD) | |
| Target length (LT) | feet |
| Target mean width (WT) | feet |
| Target vulnerability, P(k/h) (PKH) | |
| Target altitude (ALT) | feet |
| Target skin thickness (TTH) | inches |
| Target skin material (MAT) | 1.0=Aluminum<br>2.0=Fiberglass/Kevlar<br>3.0=Steel |

12. After entering the above data, you will be presented with an initial velocity table built around your desired kill radius. The initial velocities will be listed as a function of fragment mass and impact velocity. Also provided will be the ballistic limit velocities for each of the fragment masses. Input the following parameters as decimal values:

| | |
|---|---|
| Fragment mass (IFMLB(1)) | grains |
| Impact velocity (VHIT(1)) | ft/sec |

13. You will now be presented with a shopping list of warheads developed for a range of Pd's. The warheads are described by the following quantities:

Warhead weight in pounds (total weight)
Case thickness in inches
Core diameter in inches
Number of fragments from the warhead
Number of fragments hitting the target
Edge length of the fragments in inches

Input the following parameter as a decimal value:

Desired probability of a hit given a detonation (PDF)

14. If you desire to rerun the problem, or want to run a new problem, answer the questions appropriately when asked by the terminal after the execution of the current problem.

15. To receive the printout of your encounters, answer "no" to rerunning or restarting the problem when asked by the terminal and follow the directions presented on the screen.

16. Upon completion of the program, type "LOGOFF" and press ENTER.

17. Turn the terminal off with the red I O switch.

## C. EXAMPLE PROBLEMS

### 1. Example III-A

It was desired to build a warhead which would kill a typical cruise missile flying at 100 feet altitude. The warhead was required to have a lethal radius of 50 feet with a Pd of 0.98. TNT was selected for the explosive and steel was chosen for the case material. The diameter of the missile was 13.5 inches.

Table (III-3) outlines the input parameters. Table (III-4) shows the program output. After the initial velocity table was displayed at the terminal, the fragment mass was chosen to be 130 grains and the impact velocity was selected to be 2500 feet per second. After the Pd table was displayed, 0.98 was entered as the kill probability.

2. Example III-B

A warhead was required which would kill a typical manned aircraft at 30000 feet. A lethal radius of 75 feet was specified. The warhead was limited in weight to 50 pounds and needed to have a core diameter of at least 5 inches. The diameter of the missile was 10.0 inches. HMX was chosen as the explosive and depleted uranium as the case material.

Table (III-5) outlines the input parameters. Table (III-6) shows the program output. After the initial velocity table was displayed at the terminal, the fragment mass was chosen to be 210 grains and the impact velocity was selected to be 5000 feet per second. After the Pd table was displayed, it was determined that the fragments were too large and the fragment mass was then reduced to 100 grains. The impact velocity was also reduced to 3000 feet per second. When the Pd table was redisplayed, 0.995 was chosen as the desired kill probability.

## TABLE (III-3). INPUT DATA FOR EXAMPLE III-A

```
 THE FOLLOWING IS A SUMMARY OF THE INPUT DATA:
01) EXPLOSIVE DENSITY                          0.05740 LB/CU.IN
02) EXPLOSIVE GURNEY CONSTANT                  7600.00 FT/SEC
03) EXPLOSIVE DETONATION VELOCITY             21785.00 FT/SEC
04) CASE MATERIAL DENSITY                       0.2830 LB/CU.IN
05) DESIRED KILL RADIUS                           50.0 FEET
06) WARHEAD DIAMETE                              13.50 INCHES
07) WARHEAD LENGTH-TO-DIAMETER RATIO              2.50
08) TARGET LENGTH                                36.00 FEET
09) TARGET WIDTH                                  3.50 FEET
10) TARGET VULNERABILITY, P(K/H)                 0.150
11) TARGET ALTITUDE                               100. FEET
12) TARGET SKIN THICKNESS                        0.060 INCHES
13) TARGET SKIN MATERIAL                         STEEL
```

## TABLE (III-4). OUTPUT DATA FOR EXAMPLE III-A

```
INITIAL VELOCITY TABLE FOR  50.0 FT KILL RADIUS
 IMPACT                        FRAGMENT MASSES
VELOCITY    50 GR.   100 GR.   150 GR.   200 GR.    250 GR.    300 GR.
  1000.    2513.      2078.     1895.     1787.      1714.      1661.
  2000.    5027.      4156.     3789.     3574.      3429.      3321.
  3000.    7540.      6235.     5684.     5361.      5143.      4982.
  4000.   10054.      8313.     7579.     7148.      6857.      6643.
  5000.   12567.     10391.     9473.     8936.      8571.      8303.
  6000.   15081.     12469.    11368.    10723.     10286.      9964.
BALLISTIC
LIMIT        641.       533.      476.      439.       412.       391.

FRAGMENT MASS........ 130.0 GRAINS
IMPACT VELOCITY...... 2500. FT/SEC

           WARHEAD      CASE       CORE     ---------FRAGMENTS---------
   PD       WEIGHT   THICKNESS  DIAMETER   NUMBER   ON TARGET   LENGTH
  0.999    183.17      0.55      10.51    3587.64     71.94       0.35
  0.990    139.85      0.48      11.14    2392.40     47.98       0.37
  C.980    125.45      0.45      11.35    2032.49     40.76       0.38
  0.950    105.03      0.41      11.65    1556.62     31.22       0.40
  0.900     88.15      0.38      11.89    1196.59     24.00       0.42

KILL PROBABILITY..... 0.980

WARHEAD DESCRIPTION---------------------------------

   WARHEAD WEIGHT                       125.45 POUNDS
   EXPLOSIVE WEIGHT                      45.39 POUNDS
   CASE WEIGHT                           80.07 POUNDS
   CASE THICKNESS                       0.4513 INCHES
   CORE DIAMETER                         11.35 INCHES
   FRAGMENT WEIGHT                      130.00 GRAINS
   FRAGMENT DIMENSIONS  0.381 X 0.381 X 0.451 INCHES
   NUMBER OF FRAGMENTS                   2032.
   NUMBER OF HITS ON TARGET                41.
   PROBABILITY OF KILL (PD)             0.980
   INITIAL FRAGMENT VELOCITY            4886.8 FT/SEC
   CRITICAL MISS DISTANCE               1912.1 FEET
```

TABLE (III-5). INPUT DATA FOR EXAMPLE III-B

```
  THE FOLLOWING IS A SUMMARY OF THE INPUT DATA:
01) EXPLOSIVE DENSITY                            0.06650 LB/CU.IN
02) EXPLOSIVE GURNEY CONSTANT                   10230.00 FT/SEC
03) EXPLOSIVE DETONATION VELOCITY               29934.00 FT/SEC
04) CASE MATERIAL DENSITY                         0.6880 LB/CU.IN
05) DESIRED KILL RADIUS                             75.0 FEET
06) WARHEAD DIAMETE                                10.00 INCHES
07) WARHEAD LENGTH-TO-DIAMETER RATIO                2.00
08) TARGET LENGTH                                  60.00 FEET
09) TARGET WIDTH                                   20.00 FEET
10) TARGET VULNERABILITY, P(K/H)                   0.100
11) TARGET ALTITUDE                               30000. FEET
12) TARGET SKIN THICKNESS                          0.180 INCHES
13) TARGET SKIN MATERIAL                        ALUMINUM
```

## TABLE (III-6). OUTPUT DATA FOR EXAMPLE III-B

```
INITIAL VELOCITY TABLE FOR  75.0 FT KILL RADIUS
 IMPACT                         FRAGMENT MASSES
VELOCITY    50 GR.    100 GR.   150 GR.   200 GR.   250 GR.   300 GR.
  1000.     1329.     1253.     1218.     1196.     1181.     1170.
  2000.     2658.     2507.     2436.     2393.     2362.     2339.
  3000.     3988.     3760.     3654.     3589.     3543.     3509.
  4000.     5317.     5014.     4873.     4785.     4724.     4678.
  5000.     6646.     6267.     6091.     5982.     5905.     5848.
  6000.     7975.     7521.     7309.     7178.     7087.     7017.
BALLISTIC
LIMIT        329.      277.      249.      231.      217.      207.

FRAGMENT MASS........ 210.0 GRAINS
IMPACT VELOCITY...... 5000. FT/SEC

           WARHEAD      CASE       CORE     ---------FRAGMENTS---------
   PD       WEIGHT   THICKNESS   DIAMETER   NUMBER   ON TARGET   LENGTH
  0.999     90.17      0.27        7.95    1480.22     75.39      0.40
  0.990     68.82      0.23        8.41     986.93     50.26      0.43
  0.980     61.73      0.22        8.56     838.42     42.70      0.44
  0.950     51.67      0.20        8.77     642.08     32.70      0.46
  0.900     43.3       0.19        8.95     493.54     25.14      0.48

INITIAL VELOCITY TABLE FOR  75.0 FT KILL RADIUS
 IMPACT                         FRAGMENT MASSES
VELOCITY    50 GR.    100 GR.   150 GR.   200 GR.   250 GR.   300 GR.
  1000.     1329.     1253.     1218.     1196.     1181.     1170.
  2000.     2658.     2507.     2436.     2393.     2362.     2339.
  3000.     3988.     3760.     3654.     3589.     3543.     3509.
  4000.     5317.     5014.     4873.     4785.     4724.     4678.
  5000.     6646.     6267.     6091.     5982.     5905.     5848.
  6000.     7975.     7521.     7309.     7178.     7087.     7017.
BALLISTIC
LIMIT        329.      277.      249.      231.      217.      207.

FRAGMENT MASS........ 100.0 GRAINS
IMPACT VELOCITY...... 3000. FT/SEC
```

TABLE (III-6). CONTINUED

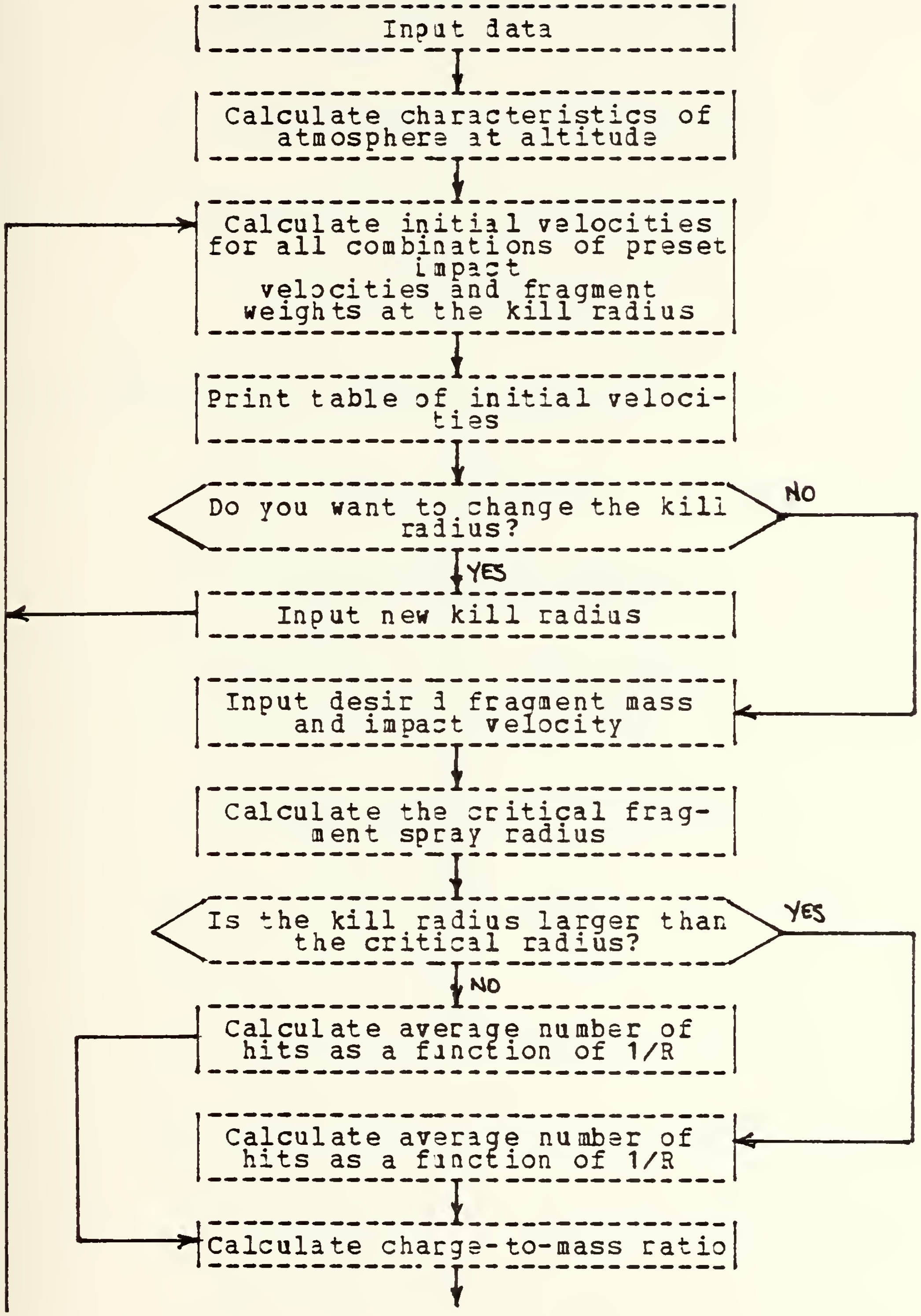
```
            WARHEAD      CASE        CORE     ---------FRAGMENTS---------
   PD       WEIGHT    THICKNESS   DIAMETER  NUMBER    ON TARGET   LENGTH
 0.999       52.41       0.36       8.92    1306.57     66.54       0.24
 0.990       40.00       0.32       9.10     871.07     44.36       0.26
 C.980       35.87       0.30       9.16     739.97     37.69       0.26
 0.950       30.03       0.27       9.25     566.66     28.86       0.27
 0.900       25.20       0.25       9.33     435.55     22.18       0.29

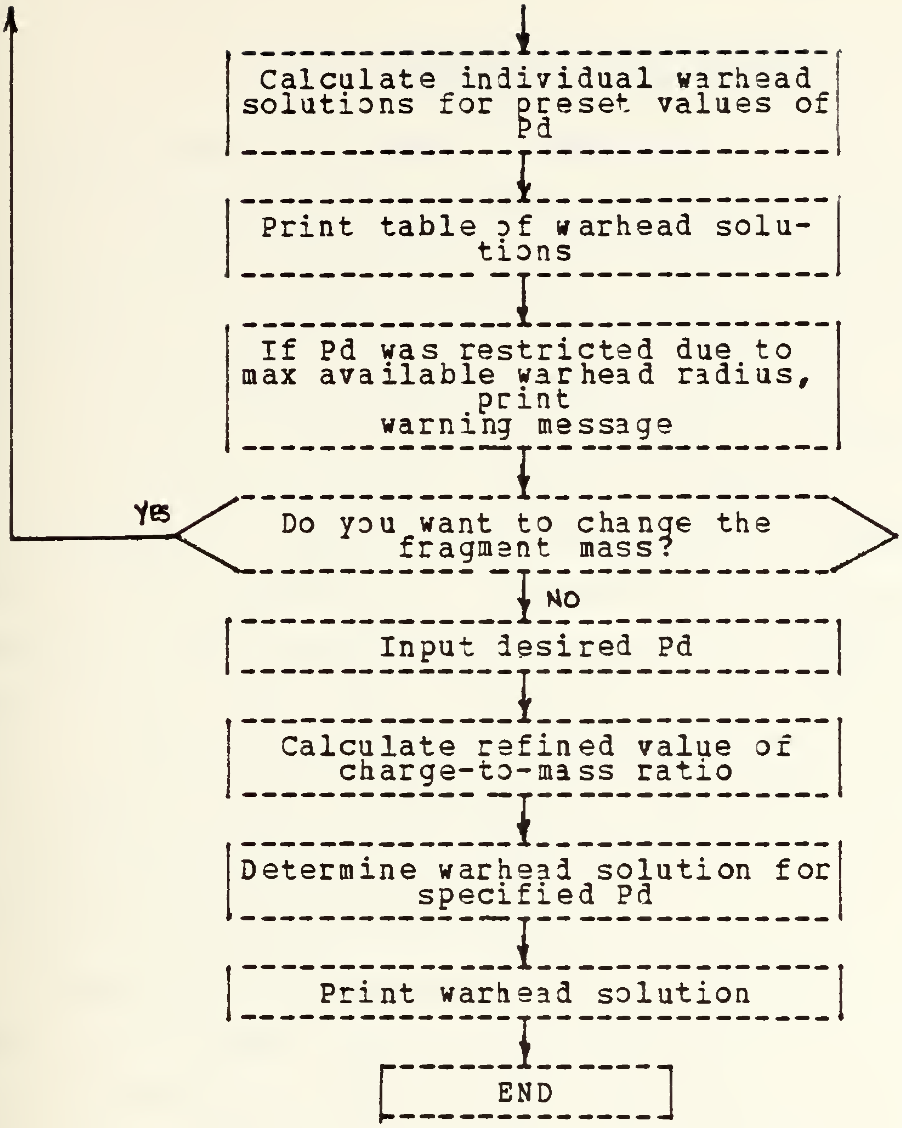
KILL PROBABILITY..... 0.995

WARHEAD DESCRIPTION----------------------------------

   WARHEAD WEIGHT                       43.91 POUNDS
   EXPLOSIVE WEIGHT                      5.67 POUNDS
   CASE WEIGHT                          38.24 POUNDS
   CASE THICKNESS                      0.3322 INCHES
   CORE DIAMETER                         9.04 INCHES
   FRAGMENT WEIGHT                     100.00 GRAINS
   FRAGMENT DIMEN IONS   0.250 X 0.250 X 0.332 INCHES
   NUMBER OF FRAGMENTS                  1002.
   NUMBER OF HITS ON TARGET               51.
   PROBABILITY OF KILL (PD)            0.995
   INITIAL FRAGMENT VELOCITY           3760.3 FT/SEC
   CRITICAL MISS DISTANCE              6230.0 FEET
```

## D. PROCEDURAL FLOWCHART


Input data
Calculate characteristics of atmosphere at altitude
Calculate initial velocities for all combinations of preset impact velocities and fragment weights at the kill radius
Print table of initial velocities
Do you want to change the kill radius?
NO
YES
Input new kill radius
Input desired fragment mass and impact velocity
Calculate the critical fragment spray radius
Is the kill radius larger than the critical radius?
YES
NO
Calculate average number of hits as a function of 1/R
Calculate average number of hits as a function of 1/R
Calculate charge-to-mass ratio


Calculate individual warhead solutions for preset values of Pd
Print table of warhead solutions
If Pd was restricted due to max available warhead radius, print warning message
YES
Do you want to change the fragment mass?
NO
Input desired Pd
Calculate refined value of charge-to-mass ratio
Determine warhead solution for specified Pd
Print warhead solution
END

# IV. PROPULSION MOTOR SIZING

## A. DESCRIPTION AND ORIGIN OF PROGRAM

This program provides a method for the preliminary sizing of a solid propellant rocket motor for a boost-sustain trajectory of a tactical missile. The analytical method was developed by Redmon [Ref. 1] and was expanded with the addition of material from Platzek [Ref. 2] and Hill [Ref. 3]. The program was written for this thesis in FORTRAN IV for use on the IBM 370 computer system. Essentially, the analysis consists of sizing the booster motor from differential velocity and acceleration requirements with limitations imposed by the physical dimensions of the missile. The booster is at all times considered to be a core-burning motor. The sustainer motor calculations are controlled by the maximum range specified by the user and by the solution of the booster motor. The sustainer can be either a core-burning or an end-burning motor.

The rocket motor configuration is assumed to be either an integral booster-sustainer motor as shown in Figure (IV-1) or a staged motor as in Figure (IV-2). The booster and the sustainer always burn exclusively, or, in other words, one is not burning while the other one is. The nozzle half angle is specified by the user consistant with space available in the missile. If a staged motor is utilized, both nozzles will have the same half angle.

The booster calculations start by determining the amount of thrust needed to boost the total weight of the missile to its cruise velocity at the prescribed acceleration. From this, the necessary amount of propellant is estimated and the process is iterated to account for the decreasing mass situation. The chamber pressure is initially estimated by

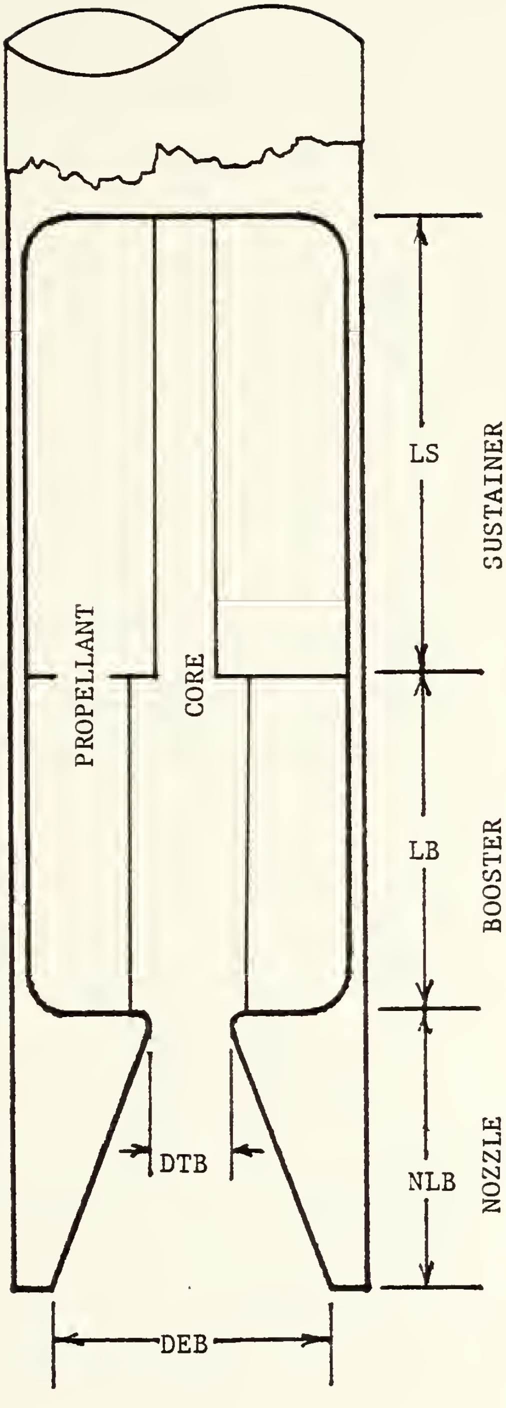


Figure (IV-1). Integral booster-sustainer motor

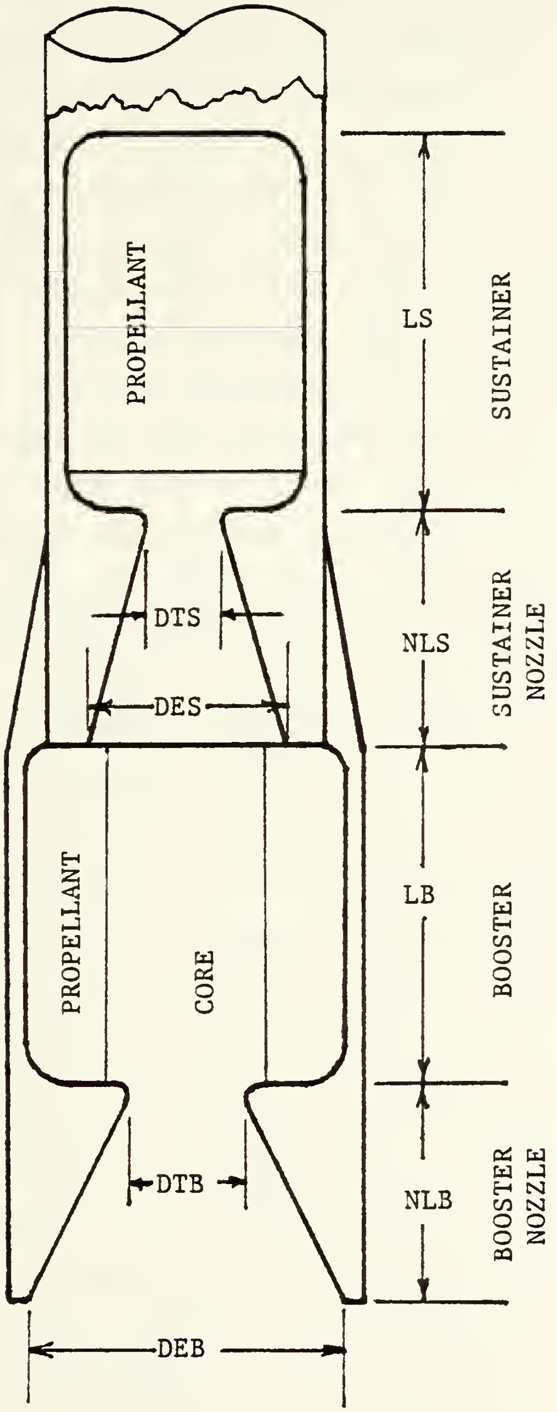


Figure (IV-2). Staged motor

minimizing the motor weight to propellant specific impulse ratio, as presented by Redmon [Ref. 1]. The next step of the program is to size the nozzle using the now known initial pressure ratio. Once the ideal nozzle is developed, the chamber pressure is raised or lowered as necessary in an attempt to cause the nozzle exit diameter to exactly match the booster diameter. However, if the integral motor option is used, the program will drive the nozzle as small as it can without violating one of the following limits in order to increase the probability that the sustainer will operate properly. The iterative process has two limits: an absolute maximum of 2000 PSI chamber pressure [Ref. 2] and a minimum of 1000 PSI if the pressure had previously been higher. The solution can be less than 1000 PSI if the pressure remained below that level throughout the problem. Also limited is the exit pressure to ambient pressure ratio. At the low end, it is limited to 0.4 to prevent flow separation in the nozzle. At the high end, it is limited to 2.5 to prevent excessive underexpansion and loss of physical reality in the program results [Ref. 4]. The burn rate is initialized at a potential maximum of 1.25 inches/second [Ref. 2] and is allowed to decrease to arrive at a compatible burn area and web thickness combination.

The sustainer motor, in the integral motor case, is virtually a continuation of the booster solution. The initial thrust requirement is determined by increasing the cruise speed drag to account for speed loss through maneuvers. It is also then refined for weight change if any climbing or diving is required to reach the target altitude. The nozzle is the same one as developed for the booster except that the throat area will be expanded as a result of the erosion effect. From the new area ratio, a pressure ratio is determined. The chamber pressure and thrust coefficient are then

iterated until a steady chamber pressure evolves to provide the required thrust. If at any time it drops below 125 PSI, the program will stop since this is considered a minimum chamber pressure for proper propellant combustion. The exit pressure to ambient pressure ratio remains subject to the same restrictions. The burn rate starts at 0.45 inches/second [Ref. 2] and is decreased to provide an acceptable web thickness and burn area. The solution can be either an end burner or a core burner, depending on the burn area required.

The sustainer for the staged motor is solved in essentially the same manner as the booster. The two major exceptions are that it can produce an end burner if the burn area is small enough and the thrust required is based on the cruise drag and not the velocity to be gained. The chamber pressure is limited to an absolute maximum of 800 PSI and a minimum of 250 PSI if the pressure had previously been higher [Ref. 2]. The same pressure ratio restrictions apply and the burn rate starts at 0.45 inches/second.

Other motor-nozzle combinations can be created from the results of this program on a first-order approximation basis. Figures (IV-3) and (IV-4) illustrate two possible methods for separating the motor nozzles without resorting to staging. Although these two methods will probably have the same weight disadvantage that staging does, they can be packaged in to a smaller volume of space. A hint for "creative construction" is to rerun the problem after sizing the motors using a smaller missile diameter to force the nozzles to a smaller size.

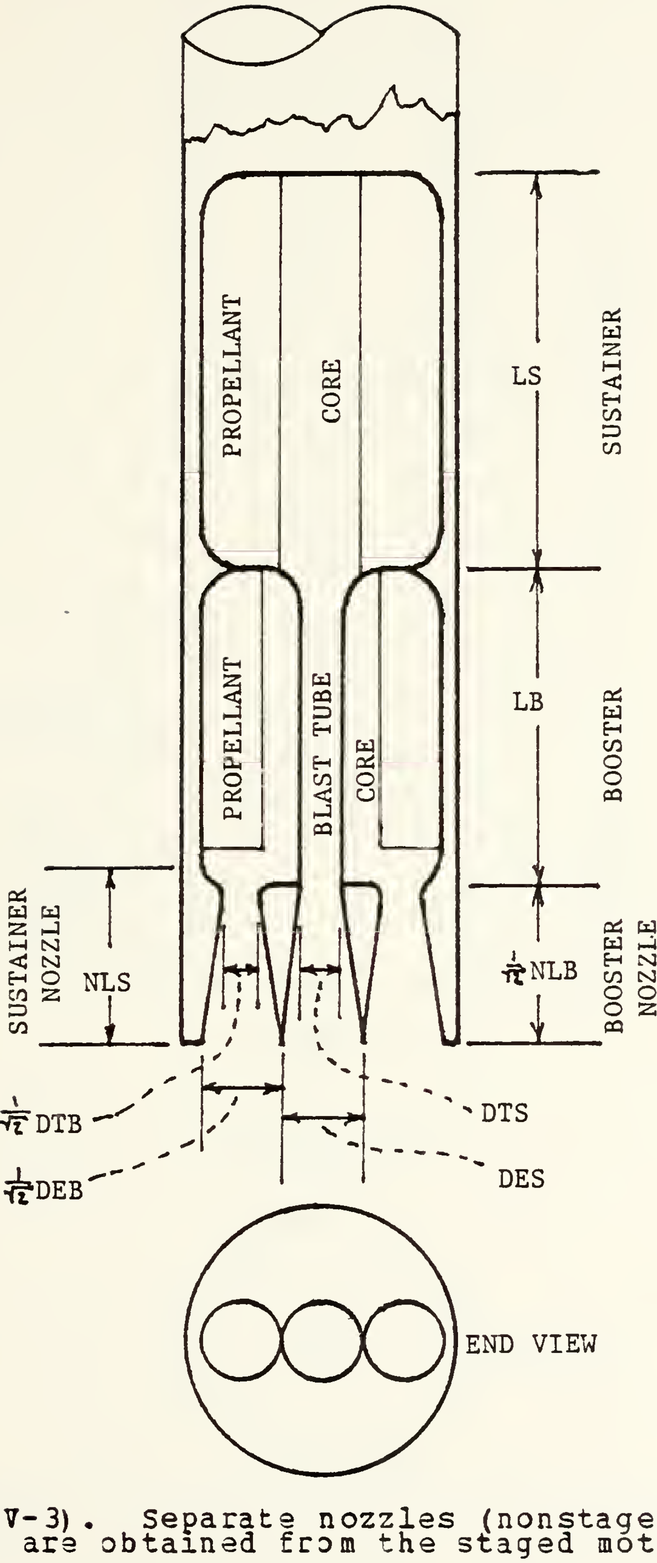


Figure (IV-3). Separate nozzles (nonstaged motors)
The values are obtained from the staged motor option.

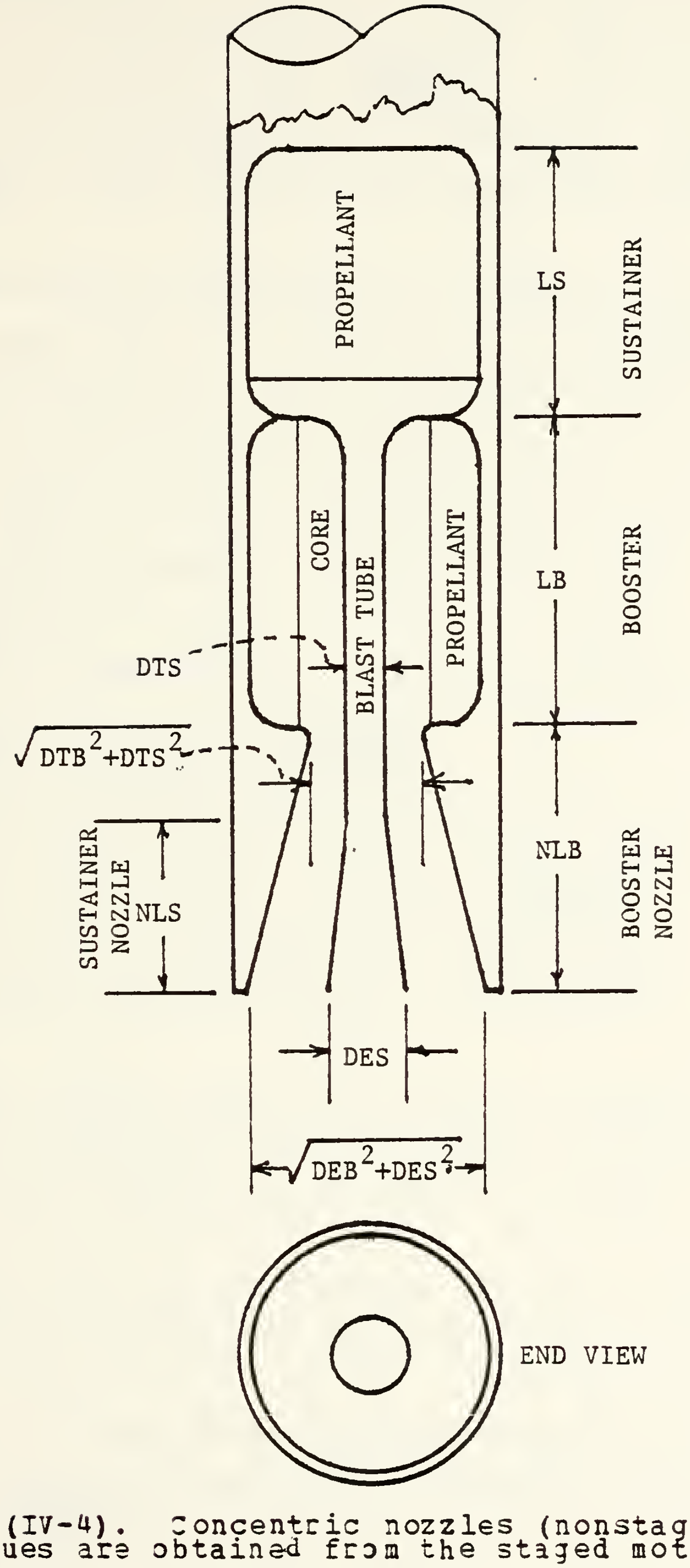


Figure (IV-4). Concentric nozzles (nonstaged motors) The values are obtained from the staged motor option.

## B. USER INSTRUCTIONS

If it is desired to abort the operation of this program prematurely, two methods are available. When the program is waiting for data entry, press ENTER. When the program is not waiting for data entry but is processing, type "HX" and press ENTER. Both actions will return the terminal to CMS mode.

When the screen becomes full, or "MORE...." appears in the status area, clear the screen by pressing ALT and CLEAR simultaneously. At several points in the program, the user will be directed to "CLEAR SCREEN AND INPUT 0". This is to provide proper positioning of the output on the screen for ease of reading. If any other symbol than "4 A ▨" should appear in the lower left of the screen, press RESET and continue.

1. Turn the terminal on with the red I O switch.

2. When the large "NPS" appears after about 30 seconds, press RESET, then press ENTER.

3. When "CP READ" appears in the status area on the lower right of the screen, type "L nnnnP", where nnnn is your 4-digit user number, then press ENTER.

4. You will now be asked for your password. Type it in (the characters will not appear on the screen), then press ENTER.

5. Your personal file must contain a PROFILE EXEC routine with the appropriate Fortran GLOBAL statement. If it does not, type "GLOBAL TXTLIB FORTMOD2 MOD2EEH", then press ENTER.

6. Type "LINK TO xxxxP 191 AS 192 RR", where xxxx is the 4-digit user number for the project file, then press ENTER.

7. You will now be asked for the project file password. Type it in (the characters will not appear on the screen), then press ENTER.

8. Type "ACCESS 192 B" and press ENTER.

9. Press ALT and CLEAR simultaneously to clear screen.

10. Type "LPROP" and press ENTER.

11. Input the following data as it is requested on the screen by typing the data and then pressing ENTER. Ensure that the data is input as either decimal or integer as specified. The terms in parenthesis are the program variable names.

The following variables are required inputs for both motor option problems.

| | | |
|---|---|---|
| Motor option | (IMOTOR) | 0=integral motors<br>1=staged motors |
| Launch altitude | (LALT) | feet |
| Launch weight | (WL) | pounds |
| Launch velocity | (VBI) | feet/second |
| Launch elevation angle | (ELB) | degrees |
| Boost acceleration | (A) | gravities |
| Cruise velocity | (VBF) | feet/second |
| Cruise velocity drag | (DRAGS) | pounds |
| Maximum range to target | (R) | nautical miles |
| Maximum target altitude | (TALT) | feet |
| Booster propellant specific impulse | (ISPB) | seconds |
| Booster propellant density | (DENSB) | pounds/cu. inch |
| Booster exhaust specific heat ratio | (GB) | |
| Sustainer propellant specific impulse | (ISPS) | seconds |
| Sustainer propellant density | (DENSS) | pounds/cu. inch |
| Sustainer exhaust specific heat ratio | (GS) | |
| Nozzle half angle | (ALN) | degrees |

The following variables are required inputs for the integral motors option only.

| | | |
|---|---|---|
| Nozzle design altitude | (ALTBN) | feet |
| Nozzle erosion rate | (ER) | inches/second |
| Missile diameter | (DB) | inches |
| Case yield strength | (YIELD) | PSI |
| Case density | (DENSC) | pounds/cu. inch |

The following variables are required inputs for the staged motors option only.

| | | |
|---|---|---|
| Booster design altitude | (ALTBN) | feet |
| Booster diameter | (DB) | inches |
| Booster case yield strength | (YIELD) | PSI |
| Booster case density | (DENSC) | pounds/cu. inch |
| Sustainer design altitude | (ALTSN) | feet |
| Sustainer diameter | (D) | inches |
| Sustainer case yield strength | (YIELD) | PSI |
| Sustainer case density | (DENSCS) | pounds/cu. inch |

12. This program will cue the user when the input parameters have dictated a scenario which either cannot be achieved within reality or produce less than optimum requirements on the propulsion system of the missile. They are not definitive and are only intended to make the user aware of a situation which may need correction. The following is a list of available cue messages with short definitions.

"SUSTAINER NOT CALCULATED SINCE THE BOOSTER BURNOUT RANGE EXCEEDS THE DESIGN RANGE." This can result from entering an extremely short range for the missile, or it can be caused by a very low acceleration requirement.

"SUSTAINER NOT CALCULATED; THE BOOSTER NOZZLE DESIGN PREVENTS SUSTAINER OPERATION. RECOMMEND STAGING OR INDEPENDENT NOZZLES." This occurs only when using the integral motors option. Then scenario described to the program can cause the booster nozzle to be too large to

maintain the proper chamber pressures when the motor has shifted to sustainer operation. This usually occurs when a large acceleration is demanded but the thrust required for the cruise trajectory is small.

"BOOSTER BURN RATE WAS ADJUSTED TO CORRESPOND WITH THE WEB THICKNESS." This occurs quite often and simply indicates that the burn rate was decreased from its potential physical maximum of 1.25 inches/second.

"THE BOOSTER NOZZLE DESIGN WAS RESTRICTED DUE TO THE MISSILE DIAMETER," and "THE SUSTAINER NOZZLE DESIGN WAS RESTRICTED DUE TO THE MISSILE DIAMETER." The nozzle was not able to be designed for optimum pressure ratios at the mid point of the boost trajectory. Usually, the exit diameter is solved larger than the missile diameter and is subsequently reduced to fit.

"BOOSTER NOZZLE DESIGN IS NOT OPTIMUM DUE TO EXCESSIVE BOOSTER CHAMBER PRESSURES," and "SUSTAINER NOZZLE DESIGN IS NOT OPTIMUM DUE TO EXCESSIVE SUSTAINER CHAMBER PRESSURES." If the nozzle cannot be downsized without exceeding pressure thresholds (2000 PSI for the booster and 800 PSI for the sustainer), the chamber pressure is held just below the pressure threshold and the nozzle area ratio will be adjusted to allow the nozzle to fit in the missile.

"THE SUSTAINER MOTOR HAS A CORE-BURNING GRAIN." The required burn area for the sustainer was too large tco permit an end burning grain with a properly realistic burn rate.

"SUSTAINER BURN RATE WAS ADJUSTED TO CORRESPOND WITH THE WEB THICKNESS." This indicates the sustainer burn rate was lowered from a potential maximum of 0.45 inches/second to provide a proper web thickness.

"THE SUSTAINER MOTOR HAS AN END BURNING GRAIN." The required burn area for the sustainer was small enough to permit an end burning grain. The burn rate is then adjusted to correspond with the nonreduceable burn area.

"REESTIMATION OF LAUNCH WEIGHT IS REQUIRED FOR THESE MISSILE PERFORMANCE PARAMETERS." The scenario described to the program produced a motor whose weight is either larger than 75% of the total or less than 25% of the total.

"ENLARGEMENT OF DIAMETER IS RECOMMENDED DUE TO A VERY HIGH LENGTH-TO-DIAMETER RATIO FOR THE MOTOR." This cue indicates the length-to-diameter ratio is greater than 15. Other components of the missile will make the missile's overall length-to-diameter ratio even larger.

13. Immediately after completion of the solution, the program will ask if you want to receive a hardcopy printout of that particular solution. A "yes" answer stores that solution in a file for retrieval by the user when he finishes with the program.

14. If you desire to rerun the problem, or want to run a new problem, answer the questions appropriately when asked by the terminal after the execution of the current problem.

15. To receive the printout of your encounters, answer "no" to rerunning or restarting the problem when asked by the terminal and follow the directions presented on the screen.

16. Upon completion of the program, type "LOGOFF" and press ENTER.

17. Turn the terminal off with the red I O switch.

## C. EXAMPLE PROBLEMS

### 1. Example IV-A. Integral motors, common nozzle

The following parameters are input for the integral motor example:

| | | |
|---|---|---|
| Launch altitude | 35.0 | feet |
| Launch weight | 1000.0 | pounds |
| Launch velocity | 0.0 | feet/second |
| Launch angle | 60.0 | degrees |
| Average acceleration | 30.0 | g's |
| Cruise velocity | 4000.0 | feet/second |
| Drag at cruise velocity | 1500.0 | pounds |
| Maximum range | 20.0 | miles |
| Final (target) altitude | 50000 | feet |
| Booster propellant specific impulse | 260.0 | seconds |
| Booster propellant density | 0.075 | lbs/cu.inch |
| Booster exhaust specific heat ratio | 1.244 | |
| Sustainer propellant specific impulse | 210.0 | seconds |
| Sustainer propellant density | 0.065 | lbs/cu.inch |
| Sustainer exhaust specific heat ratio | 1.270 | |
| Nozzle half angle | 20.0 | degrees |
| Nozzle design altitude | 0.0 | feet |

TABLE (IV-1).  OUTPUT OF EXAMPLE IV-A

```
INTEGRAL MOTORS (COMMON NOZZLE)
SUMMARY OF INPUT  ARAMETERS==========================
     1) LAUNCH ALTITUDE                              35.0 FEET
     2) LAUNCH WEIGHT                              1000.00 POUNDS
     3) LAUNCH VELOCITY                               0.0 FT/SEC
     4) LAUNCH ANGLE                                 60.0 DEGREES
     5) AVERAGE ACCELERATION                         30.00 G"S
     6) CRUISE VE.OCITY                            4000.0 FT/SEC
     7) DRAG AT CRUISE VELOCITY                    1500.0 POUNDS
     8) MAXIMUM RANGE                                20. MILES
     9) FINAL (TARGET) ALTITUDE                   50000.0 FEET
    10) BOOSTER PROPELLANT SPECIFIC IMPULSE         260.0 SEC
    11) BOOSTER PROPELLANT DENSITY                 0.0750 LBS/CU.IN
    12) BOOSTER EXHAUST SPECIFIC HEAT RATIO       1.24400
    13) SUSTAINER PROPELLANT SPECIFIC IMPULSE       210.0 SEC
    14) SUSTAINER PROPELLANT DENSITY               0.0650 LBS/CU.IN
    15) SUSTAINER EXHAUST SPECIFIC HEAT RATIO     1.27000
    16) NOZZLE HALF ANGLE                           20.00 DEGREES
    17) NOZZLE DESIGN ALTITUDE                        0.0 FEET
    18) NOZZLE EROSION RATE                       0.00100 IN/SEC
    19) MISSILE DIAMETER                             10.0 INCHES
    20) YIELD STREVGTH OF CASE MATERIAL          180000.0 PSI
    21) DENSITY O  CASE MATERIAL                   0.2662 LBS/CU.IN
                                   BOOSTER                SUSTAINER
PROPELLANT WEIGHT                  393.21 LBS               253.67 LBS
CASING WEIGHT                       36.95 LBS                24.92 LBS
TOTAL WEIGHT                       430.16 LBS               278.59 LBS
THRUST COEFFICIENT                 1.6032                   1.2748
CHARACTERISTIC VELOCITY            5217.7 FT/SEC            5300.1 FT/SEC
THRUST                            24669.5 LBS               1814.2 LBS
BURN TIME                           4.144 SEC               29.364 SEC
HORIZONTAL BURNOUT RANGE            4144. FEET
CHAMBER PRESSURE                  1999.66 PSI               196.09 PSI
GRAIN BURN AREA                  1590.873 SQ.IN            910.321 SQ.IN
GRAIN WEB THICKNESS                 3.296 IN                 4.287 IN
GRAIN PORT AREA                     9.053 SQ.IN              0.982 SQ.IN
REQUIRED BURN RATE                  0.795 IN/SEC             0.146 IN/SEC
MOTOR CASE LENGTH                   79.55 IN                 53.64 IN
MOTOR CASE VOLUME                 6046.29 CU.IN            4056.20 CU.IN
NOZZLE THROAT AREA                  7.695 SQ.IN            ******* SQ.IN
NOZZLE EXIT AREA                   58.510 SQ.IN            ******* SQ.IN
NOZZLE LENGTH                       7.557 IN               ******* IN
NOZZLE WEIGHT                       38.88 LBS              ******* LBS
CASE THICKNESS                    0.05555 IN               0.05555 IN
TOTAL CASE WEIGHT                              61.87 LBS
TOTAL PROPELLANT WEIGHT                       646.88 LBS
```

```
                  TABLE (IV-1).  (CONTINUED)
TOTAL ROCKET MOTOR WEIGHT                      747.62 LBS
TOTAL ROCKET MOTOR LENGTH                      140.74 IN

BOOSTER BURN RATE WAS ADJUSTED TO CORRESPOND WITH THE WEB THICKNESS.

THE BOOSTER NOZZLE DESIGN WAS RESTRICTED DUE TO THE MISSILE DIAMETER.

BOOSTER NOZZLE DESIGN IS NOT OPTIMUM DUE TO EXCESSIVE BOOSTER CHAMBER
PRESSURES.

THE SUSTAINER MOTOR HAS A CORE-BURNING GRAIN.

SUSTAINER BURN RATE WAS ADJUSTED TO CORRESPOND WITH THE WEB THICKNESS.
```

| | | |
|---|---|---|
| Nozzle erosion rate | 0.001 | inches/second |
| Missile diameter | 10.0 | inches |
| Yield strength of case material | 180000.0 | PSI |
| Density of case material | 0.2662 | lbs/cu.inch |

The solution for this problem is presented in Table (IV-1).

2. Example IV-B. Staged motors, separate nozzles

The following are input for the staged motor prblem:

| | | |
|---|---|---|
| Launch altitude | 35.0 | feet |
| Launch weight | 2200.0 | pounds |
| Launch velocity | 0.0 | feet/second |
| Launch angle | 30.0 | degrees |
| Average acceleration | 25.0 | g's |
| Cruise velocity | 2200.0 | feet/second |
| Drag at cruise velocity | 1000.0 | pounds |
| Maximum range | 50.0 | miles |
| Final (target) altitude | 75000 | feet |
| Booster propellant specific impulse | 250.0 | seconds |
| Booster propellant density | .0647 | lbs/cu.inch |
| Booster exhaust specific heat ratio | 1.225 | |
| Sustainer propellant specific impulse | 205.0 | seconds |
| Sustainer propellant density | .0625 | lbs/cu.inch |
| Sustainer exhaust specific heat ratio | 1.257 | |
| Nozzle half angle | 15.0 | degrees |
| Booster design altitude | 0.0 | feet |
| Booster diameter | 14.5 | inches |
| Yield strength of booster case | 180000.0 | PSI |
| Density of booster case material | 0.2662 | lbs/cu.inch |
| Sustainer design altitude | 0.0 | feet |

## TABLE (IV-2). OUTPUT OF EXAMPLE IV-B

```
STAGED MOTORS (INDEPENDENT NOZZLES)
SUMMARY OF INPUT PARAMETERS=========================
     1) LAUNCH ALTITUDE                             35.0 FEET
     2) LAUNCH WEIGHT                            2200.00 POUNDS
     3) LAUNCH VELOCITY                              0.0 FT/SEC
     4) LAUNCH ANGLE                                30.0 DEGREES
     5) AVERAGE ACCELERATION                       25.00 G"S
     6) CRUISE VELOCITY                           2200.0 FT/SEC
     7) DRAG AT CRUISE VELOCITY                   1000.0 POUNDS
     8) MAXIMUM RANGE                                50. MILES
     9) FINAL (TARGET) ALTITUDE                  75000.0 FEET
    10) BOOSTER PROPELLANT SPECIFIC IMPULSE        250.0 SEC
    11) BOOSTER PROPELLANT DENSITY                0.0647 LBS/CU.IN
    12) BOOSTER EXHAUST SPECIFIC HEAT RATIO      1.22500
    13) SUSTAINER PROPELLANT SPECIFIC IMPULSE      205.0 SEC
    14) SUSTAINER PROPELLANT DENSITY              0.0625 LBS/CU.IN
    15) SUSTAINER EXHAUST SPECIFIC HEAT RATIO    1.25700
    16) NOZZLE HALF ANGLE                          15.00 DEGREES
    17) BOOSTER DESIGN ALTITUDE                      0.0 FEET
    18) BOOSTER DIAMETER                           14.50 INCHES
    19) YIELD STRENGTH OF BOOSTER CASE          180000.0 PSI
    20) DENSITY OF BOOSTER CASE MATERIAL          0.2662 LBS/CU.IN
    21) SUSTAINER DESIGN ALTITUDE                    0.0 FEET
    22) SUSTAINER DIAMETER                         14.50 INCHES
    23) YIELD STRENGTH OF SUSTAINER CASE        180000.0 PSI
    24) DENSITY OF SUSTAINER CASE MATERIAL        0.2662 LBS/CU.IN

                                  BOOSTER            SUSTAINER
PROPELLANT WEIGHT                  537.95 LBS          916.16 LBS
CASING WEIGHT                       59.42 LBS           11.82 LBS
TOTAL WEIGHT                       597.37 LBS          927.98 LBS
THRUST COEFFICIENT                 1.6035              1.2900
CHARACTERISTIC VELOCITY            5016.1 FT/SEC       5113.1 FT/SEC
THRUST                            49171.0 LBS          1370.9 LBS
BURN TIME                           2.735 SEC         136.997 SEC
HORIZONTAL BURNOUT RANGE            2606. FEET
CHAMBER PRESSURE                  1998.07 PSI          249.17 PSI
GRAIN BURN AREA                  2431.947 SQ.IN      2472.758 SQ.IN
GRAIN WEB THICKNESS                 3.419 IN            5.928 IN
GRAIN PORT AREA                    18.055 SQ.IN         5.018 SQ.IN
REQUIRED BURN RATE                  1.250 IN/SEC        0.043 IN/SEC
MOTOR CASE LENGTH                   63.30 IN            97.15 IN
MOTOR CASE VOLUME                 9641.00 CU.IN      15804.59 CU.IN
NOZZLE THROAT AREA                 15.347 SQ.IN         4.265 SQ.IN
NOZZLE EXIT AREA                  165.068 SQ.IN        12.894 SQ.IN
NOZZLE LENGTH                      18.804 IN            3.212 IN
```

```
                         TABLE (IV-2).  (CONTINUED)

NOZZLE WEIGHT                              33.62 LBS            46.95 LBS
CASE THICKNESS                           0.08048 IN           0.01004 IN
TOTAL CASE WEIGHT                                   71.24 LBS
TOTAL PROPELLANT WEIGHT                           1454.11 LBS
TOTAL ROCKET MOTOR WEIGHT                         1605.93 LBS
TOTAL ROCKET MOTOR LENGTH                          182.47 IN

THE BOOSTER NOZZLE DESIGN WAS RESTRICTED DUE TO THE MISSILE DIAMETER.

BOOSTER NOZZLE DESIGN IS NOT OPTIMUM DUE TO EXCESSIVE BOOSTER CHAMBER
PRESSURES.

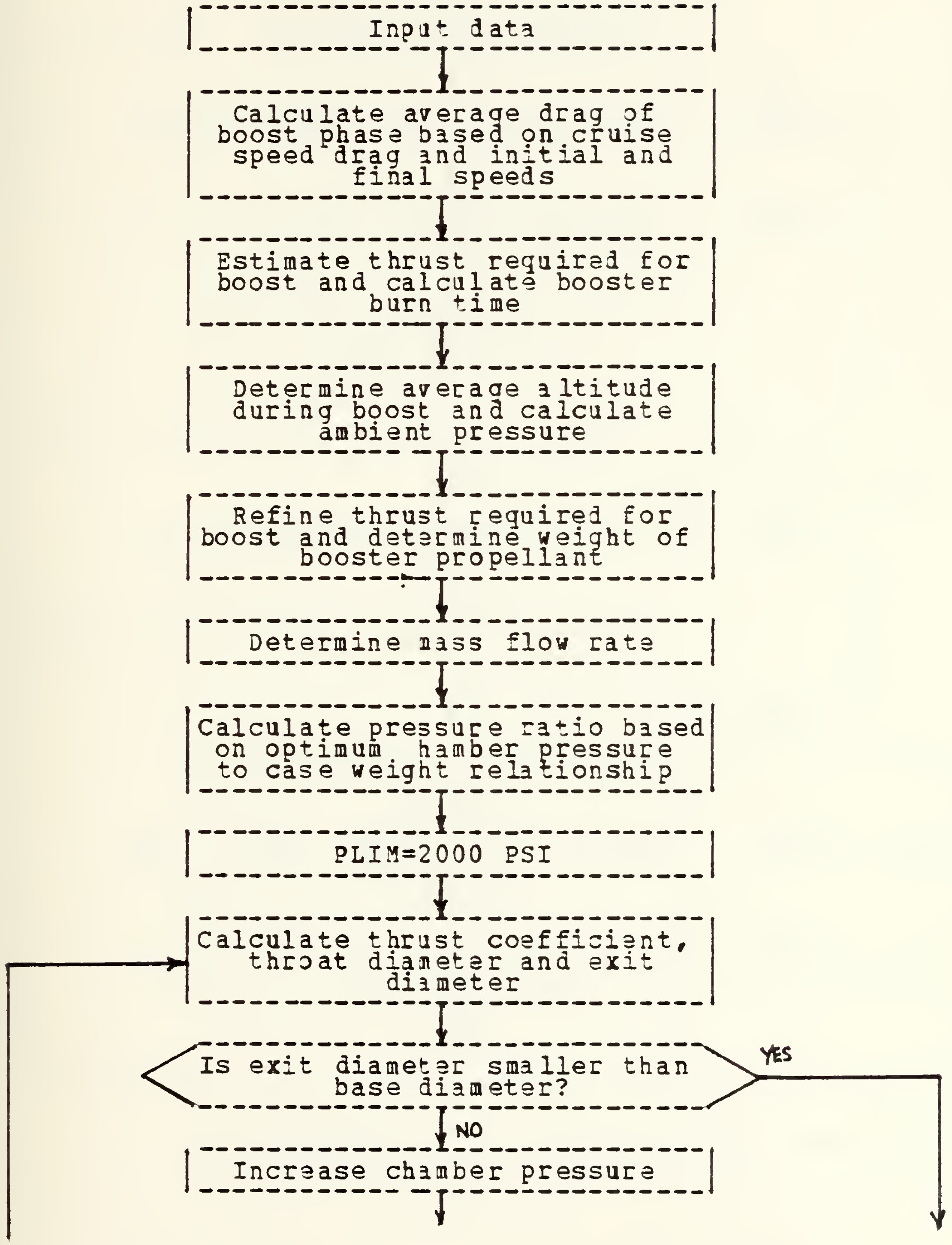
THE SUSTAINER MOTOR HAS A CORE-BURNING GRAIN.

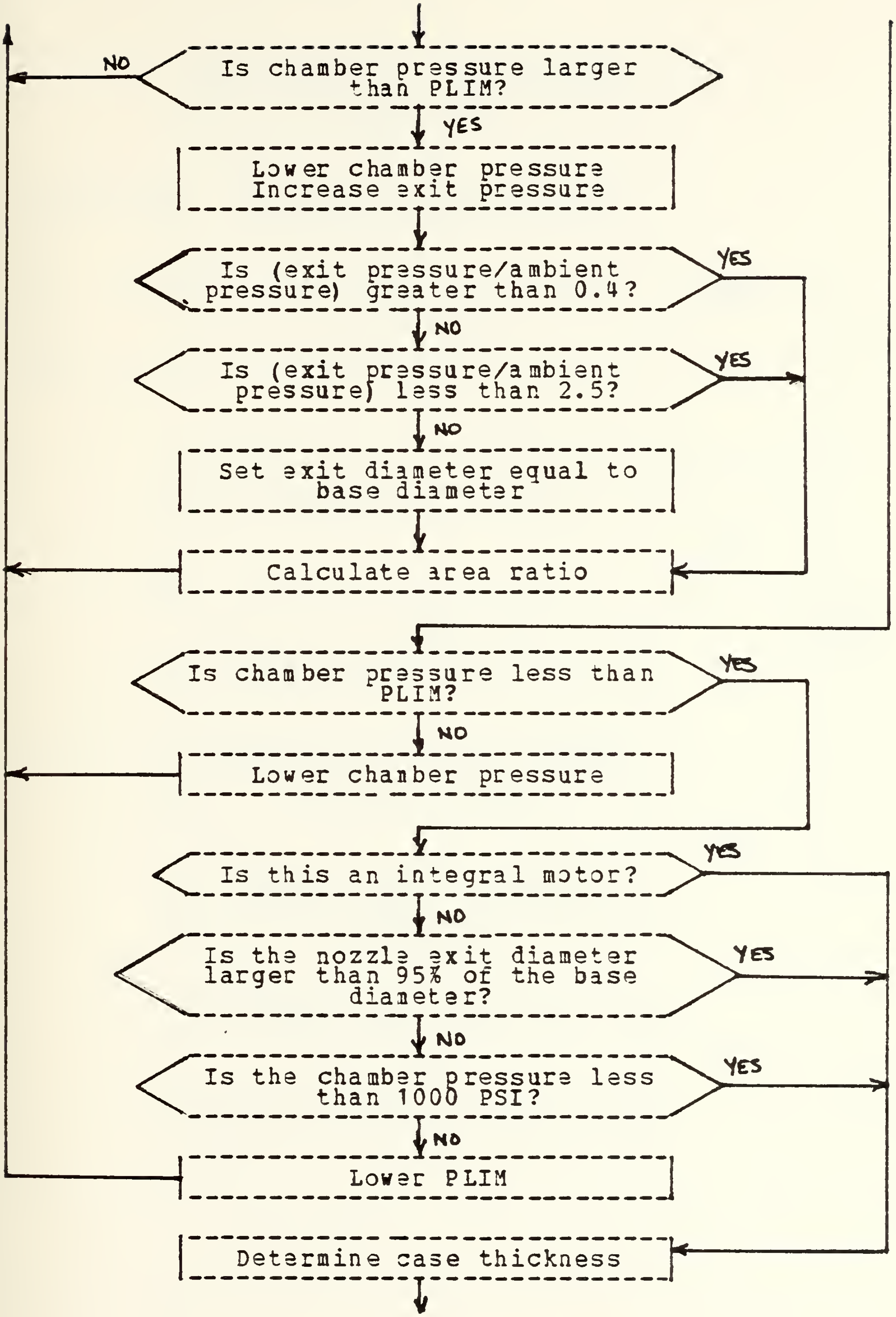
SUSTAINER BURN RATE WAS ADJUSTED TO CORRESPOND WITH THE WEB THICKNESS.
```

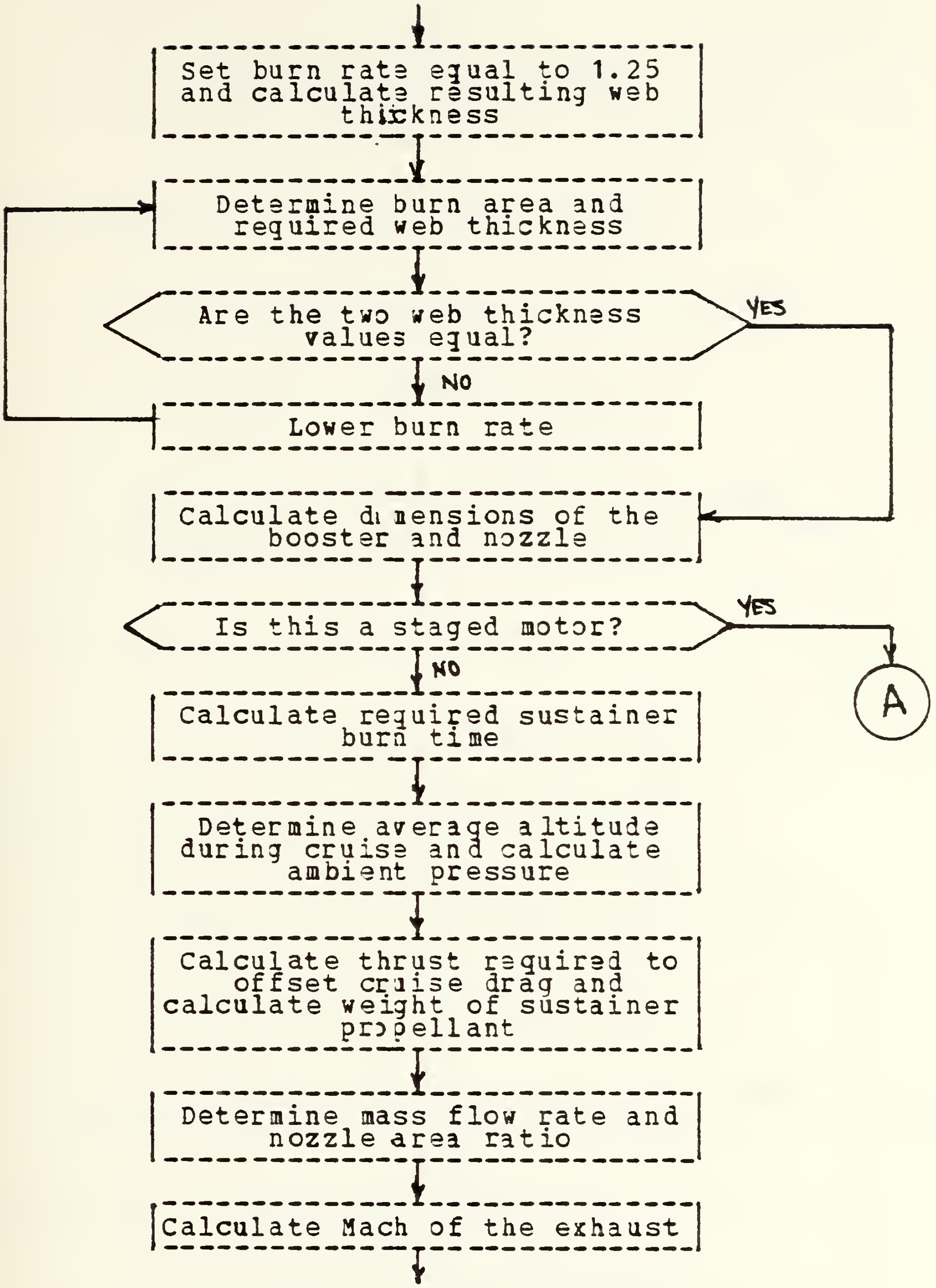
| | |
|---|---|
| Sustainer diameter | 14.5 inches |
| Yield strength of sustainer case | 180000.0 PSI |
| Density of sustainer case material | 0.2662 lbs/cu.inch |

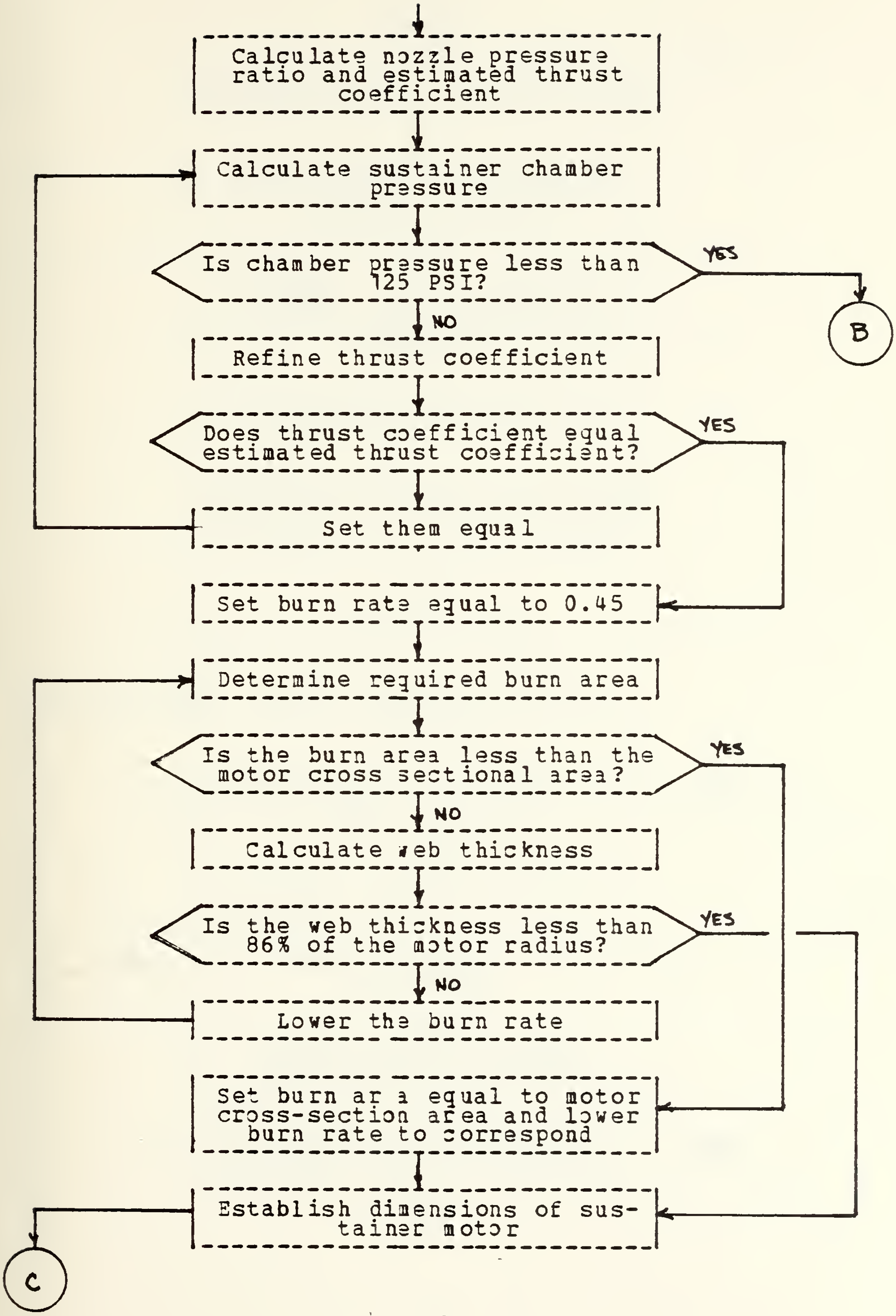
The output for this example is provided in Table (IV-2).

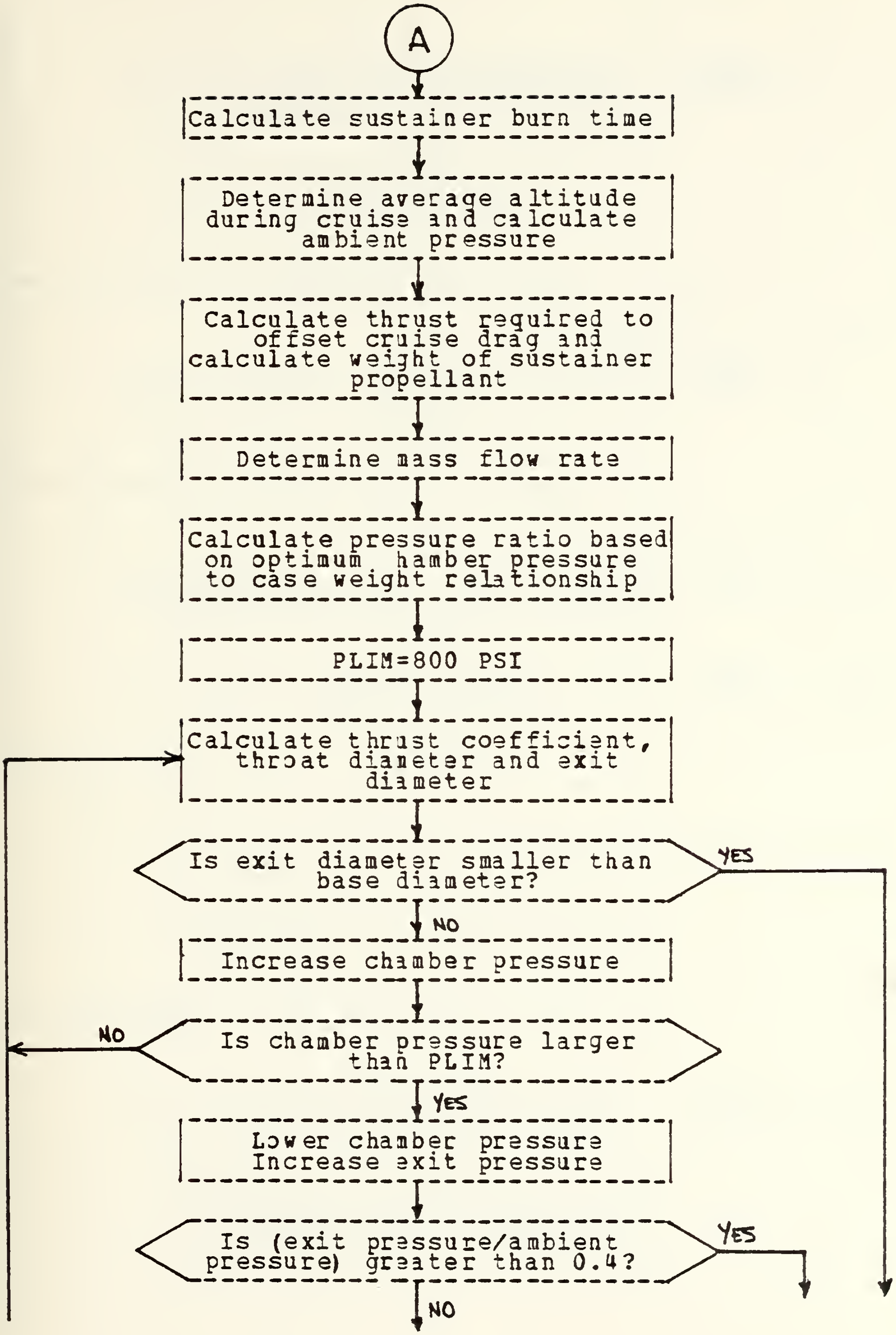
## D. PROCEDURAL FLOWCHART

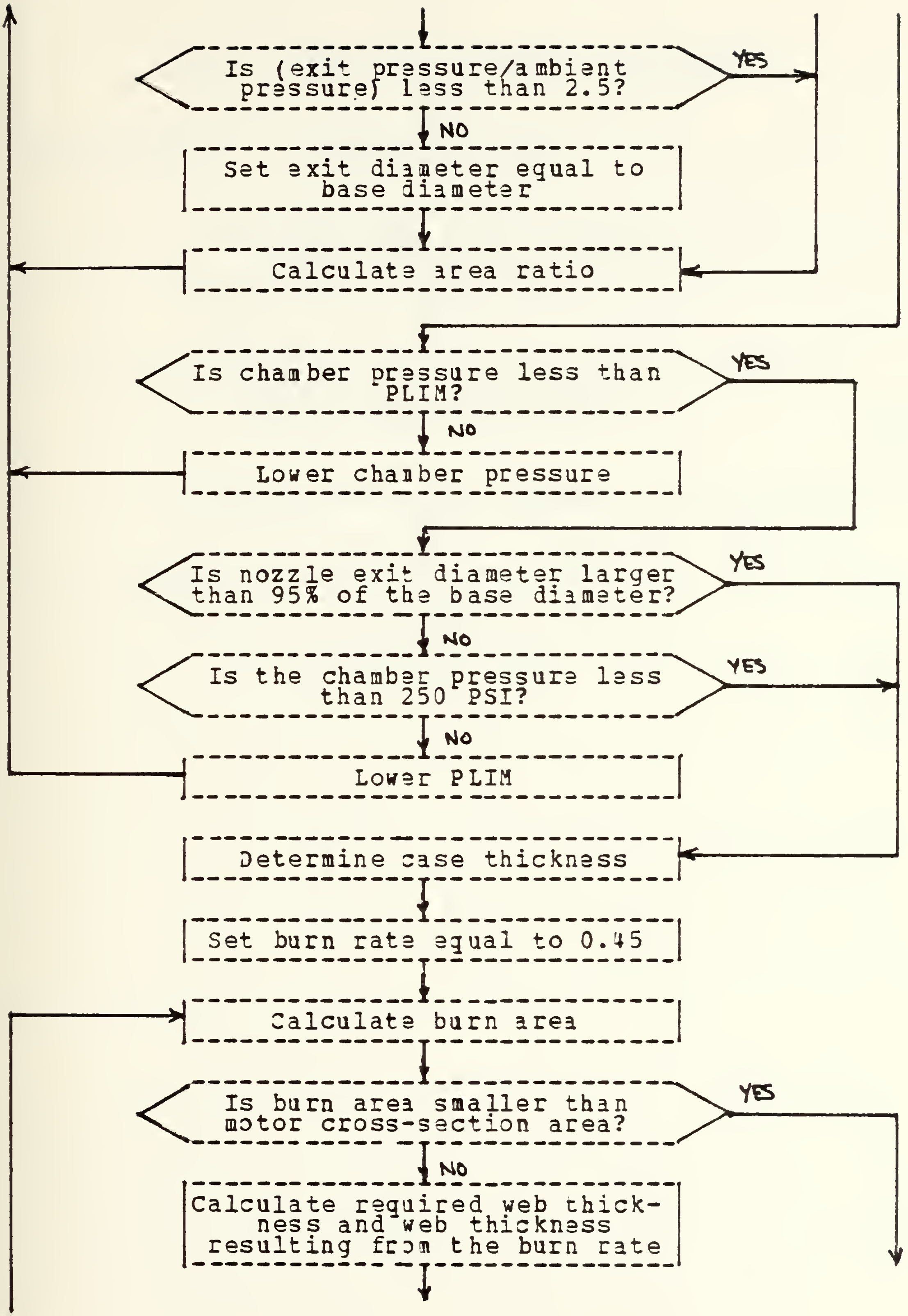

Input data
Calculate average drag of boost phase based on cruise speed drag and initial and final speeds
Estimate thrust required for boost and calculate booster burn time
Determine average altitude during boost and calculate ambient pressure
Refine thrust required for boost and determine weight of booster propellant
Determine mass flow rate
Calculate pressure ratio based on optimum hamber pressure to case weight relationship
PLIM=2000 PSI
Calculate thrust coefficient, throat diameter and exit diameter
Is exit diameter smaller than base diameter?
YES
NO
Increase chamber pressure

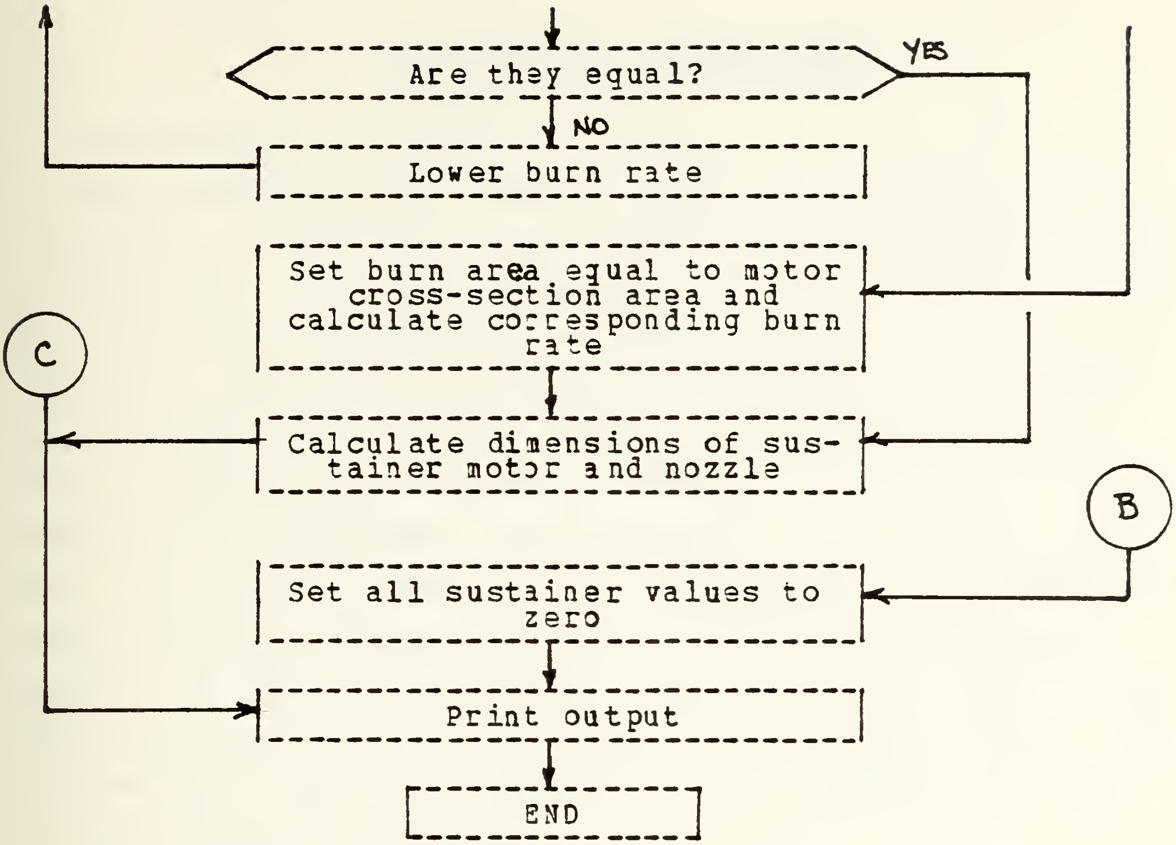

Is chamber pressure larger than PLIM?
NO
YES
Lower chamber pressure
Increase exit pressure
Is (exit pressure/ambient pressure) greater than 0.4?
YES
NO
Is (exit pressure/ambient pressure) less than 2.5?
YES
NO
Set exit diameter equal to base diameter
Calculate area ratio
Is chamber pressure less than PLIM?
YES
NO
Lower chamber pressure
Is this an integral motor?
YES
NO
Is the nozzle exit diameter larger than 95% of the base diameter?
YES
NO
Is the chamber pressure less than 1000 PSI?
YES
NO
Lower PLIM
Determine case thickness


Set burn rate equal to 1.25 and calculate resulting web thickness
Determine burn area and required web thickness
Are the two web thickness values equal?
YES
NO
Lower burn rate
Calculate dimensions of the booster and nozzle
Is this a staged motor?
YES
A
NO
Calculate required sustainer burn time
Determine average altitude during cruise and calculate ambient pressure
Calculate thrust required to offset cruise drag and calculate weight of sustainer propellant
Determine mass flow rate and nozzle area ratio
Calculate Mach of the exhaust


Calculate nozzle pressure ratio and estimated thrust coefficient
Calculate sustainer chamber pressure
Is chamber pressure less than 125 PSI?
YES
B
NO
Refine thrust coefficient
Does thrust coefficient equal estimated thrust coefficient?
YES
Set them equal
Set burn rate equal to 0.45
Determine required burn area
Is the burn area less than the motor cross sectional area?
YES
NO
Calculate web thickness
Is the web thickness less than 86% of the motor radius?
YES
NO
Lower the burn rate
Set burn area equal to motor cross-section area and lower burn rate to correspond
Establish dimensions of sustainer motor
C


A
Calculate sustainer burn time
Determine average altitude during cruise and calculate ambient pressure
Calculate thrust required to offset cruise drag and calculate weight of sustainer propellant
Determine mass flow rate
Calculate pressure ratio based on optimum hamber pressure to case weight relationship
PLIM=800 PSI
Calculate thrust coefficient, throat diameter and exit diameter
Is exit diameter smaller than base diameter?
YES
NO
Increase chamber pressure
Is chamber pressure larger than PLIM?
NO
YES
Lower chamber pressure Increase exit pressure
Is (exit pressure/ambient pressure) greater than 0.4?
YES
NO


Is (exit pressure/ambient pressure) less than 2.5?
YES
NO
Set exit diameter equal to base diameter
Calculate area ratio
Is chamber pressure less than PLIM?
YES
NO
Lower chamber pressure
Is nozzle exit diameter larger than 95% of the base diameter?
YES
NO
Is the chamber pressure less than 250 PSI?
YES
NO
Lower PLIM
Determine case thickness
Set burn rate equal to 0.45
Calculate burn area
Is burn area smaller than motor cross-section area?
YES
NO
Calculate required web thickness and web thickness resulting from the burn rate


Are they equal?
YES
NO
Lower burn rate
Set burn area equal to motor cross-section area and calculate corresponding burn rate
C
Calculate dimensions of sustainer motor and nozzle
B
Set all sustainer values to zero
Print output
END

# V. AERODYNAMIC COEFFICIENTS

## A. DESCRIPTION AND ORIGIN

This program is the current edition of a program which originated at the Naval Ship Research and Development Center in 1971 [Ref. 5]. The program was written in FORTRAN II for use on the IBM 7090 digital computer. It was developed as a method for predicting the static, longitudenal aerodynamic characteristics of typical missile configurations with the control surfaces in a "plus" attitude. The original program computed the aerodynamic characteristics for missiles operating at angles of attack up to 180 degrees. The effects of control surface deflections for all modes of aerodynamic control are taken into account. The method was based on the then well known linear, nonlinear crossflow and slender body theories with empirical modifications to provide the high angle of attack capability.

The program was modified and, presumably, updated in 1974 by F. A. Kuster, Jr., of the Naval Air Development Center. In 1980, the program was modified for use on the Naval Postgraduate School IBM 360 computer system by D. Redmon [Ref. 1]. The current version of the program was modified for use on the new Naval Postgraduate School IBM 370 computer system. It has been expanded to provide graphical presentation of the output data.

It must be emphasized at this point that the current program edition is not in a completely finished state. Somewhere in the history of the program after its initial establishment on the IBM 360, errors were introduced during the modifications. At present, these errors do not prevent the use of the program and the output data is considered to be correct for trend-observance purposes.

Specifically, the program does not produce any drag-rise phenomena for either the wings or the tails when Cd is observed as a function of Mach number. Additionally, the decline of the drag coefficient above Mach 1.0 is not smooth or as prolonged as is found experimentally. It is very probable that these two failings of the program are linked to a common error inserted accidentally in the process of tailoring the program for use on the IBM 370. In order to temporarily smooth over the graphical discontinuities, exponential decay functions were inserted. They are clearly marked in the the program listing for removal when the program is corrected.

The input to the program is composed of a detailed listing of the dimensions of the missile to be analyzed. The current version of the program will consider a missile which has four symmetrical wings and four symmetrical tails. The missile may be either canard or tail equipped and either wing or canard or tail controlled. The program assumes the control surface is the tail, however, the input data is "mislabelled" to produce the proper configuration. For instance, if the missile is a wing control missile, the wing data is input as the tail and the tail data as the wing. For a canard controlled missile, the canard data is input as the tail. Figures (V-1) and (V-3) show two typical missile configurations and where the input parameters for the program are obtained.

## B. USER INSTRUCTIONS

If it is desired to abort the operation of this program prematurely, two methods are available. When the program is waiting for data entry, press ENTER. When the program is not waiting for data entry but is processing, type "HX" and press ENTER. Both actions will return the terminal to CMS mode.

When the screen becomes full, or "MORE...." appears in the status area, clear the screen by pressing ALT and CLEAR simultaneously. At several points in the program, the user will be directed to "CLEAR SCREEN AND INPUT 0". This is to provide proper positioning of the output on the screen for ease of reading. If any other symbol than "4 A ▨" should appear in the lower left of the screen, press RESET and continue.

1. Turn the terminal on with the red | O switch.

2. When the large "NPS" appears after about 30 seconds, press RESET, then press ENTER.

3. When "CP READ" appears in the status area on the lower right of the screen, type "L nnnnP", where nnnn is your 4-digit user number, then press ENTER.

4. You will now be asked for your password. Type it in (the characters will not appear on the screen), then press ENTER.

5. Your personal file must contain a PROFILE EXEC routine with the appropriate Fortran GLOBAL statement. If it does not, type "GLOBAL TXTLIB FORTMOD2 MOD2EEH", then press ENTER.

6. Type "LINK TO xxxxP 191 AS 192 RR", where xxxx is the 4-digit user number for the project file, then press ENTER.

7. You will now be asked for the project file password. Type it in (the characters will not appear on the screen), then press ENTER.

8. Type "ACCESS 192 B" and press ENTER.

9. Press ALT and CLEAR simultaneously to clear screen.

10. Type "LAERO1" and press ENTER.

11. Input the following data as it is requested on the screen by typing the data and then pressing ENTER. Ensure

that the data is input as either decimal or integer as specified. The terms in parenthesis below are the program variable names.

Input the following as integer values unless otherwise noted. The integers must be two digit integers (three=03).

| | |
|---|---|
| Control constant (ICSC) | 01-Tail control<br>02-Wing control<br>03-Canard control |
| Nose shape (INOSE) | 01-Ellipsoid<br>02-Ogive<br>03-Cone |
| Number of control deflections (IDT)<br>You will now be asked for the control deflections in degrees, decimal values. | Less than 11 |
| Number of Mach numbers (IM)<br>You will now be asked for the Mach numbers, decimal values. Each Mach number will produce a separate table and plot of output data. | Less than 25 |
| Number of angles of attack (IAL)<br>You will now be asked for the angles of attack in degrees, decimal values. | Less than 25 |
| Number of configurations (NBODY)<br>Each configuration will restart the program. Only the last configuration will produce the written output. | No restrictions |
| Wing planform (ISWPW) | 01-Not delta<br>02-Delta |
| Wing position (IAFBW) | 00-Body after wing<br>01-No body after wing |
| Wing sweep constant (ISWEPW) | 00-Delta planform or Unswept leading edge<br>01-Swept leading edge |
| Number of wings (NWING) | 04 |
| Tail planform (ISWPT) | 01-Not delta<br>02-Delta |
| Tail position (IAFBT) | 00-No body after tail<br>01-Body after tail |
| Tail sweep constant (ISWEPT) | 00-Delta planform or Unswept leading edge<br>01-Swept leading edge |
| Number of tails (NTAIL) | 04 |

Input the following values as decimal numbers:

| | |
|---|---|
| Wing tip-to-chord ratio (XLAMW) | |
| Wing leading edge sweep (CLAMW) | Degrees |

| | |
|---|---|
| Wing span including body (BW) | Feet |
| Wing root chord (CROOTW) | Feet |
| Exposed wing area, 2 panels (SW) | Square feet |
| Wing mean geometric chord (XMACW) | Feet |
| Distance from nose to wing leading edge (XWING) | Feet |
| Wing thickness-to-chord ratio (TOVCW) | |
| Tail tip-to-chord ratio (XLAMT) | |
| Tail leading edge sweep (CLAMT) | Degrees |
| Tail span including body (BT) | Feet |
| Tail root chord (CROOTT) | Feet |
| Exposed tail area, 2 panels (ST) | Square feet |
| Tail mean geometric chord (XMACT) | Feet |
| Distance from nose to tail leading edge (XTAIL) | Feet |
| Tail thickness-to-chord ratio (TOVCT) | |
| Altitude (HT) | Feet |
| Body diameter (D) | Feet |
| Missile length (XL) | Feet |
| Nose length (XLNOSE) | Feet |
| Distance from nose to CG (XCG) | Feet |
| Reference area (AREA) | Square feet |
| Reference length (XREF) | Feet |
| Engine code (ENGINE) | 0.0-Turbofan<br>1.0-Rocket |
| Inlet code (ENLET) | 0.0-Flush<br>1.0-Extended |
| Boat tail angle (BETA) | Degrees |
| Base diameter (DBASE) | Feet |
| Nozzle exit diameter (DJET) | Feet |
| Boat tail length (XLABOD) | Feet |
| Protuberance drag (CDPROT) | (Coefficient value) |
| If comparing with experimental values, Reynolds number (REFT) | (Dimensionless) |

12. If you desire to rerun the problem, or want to run a new problem, answer the questions appropriately when asked by the terminal after the execution of the current problem.

13. To receive the printout and plot of your encounters, answer "no" to rerunning or restarting the problem when asked by the terminal and follow the directions presented on the screen.

14. Upon completion of the program, type "LOGOFF" and press ENTER.

15. Turn the terminal off with the red switch.

## C. EXAMPLE PROBLEMS

Table (V-5) identifies the output variables as they appear in the output tables.

1. Example V-A. Tail control missile

Figure (V-1) illustrates the missile used in this example. The dimensions for this missile and other input parameters are contained in Table (V-1). The output is shown in Table (V-2) and Figure (V-2).

2. Example V-II. Canard control missile

Figure (V-3) illustrates the conard configuration missile used in this example. The input data is contained in Table (V-3). The output is displayed in Table (V-4) and Figure (V-4).

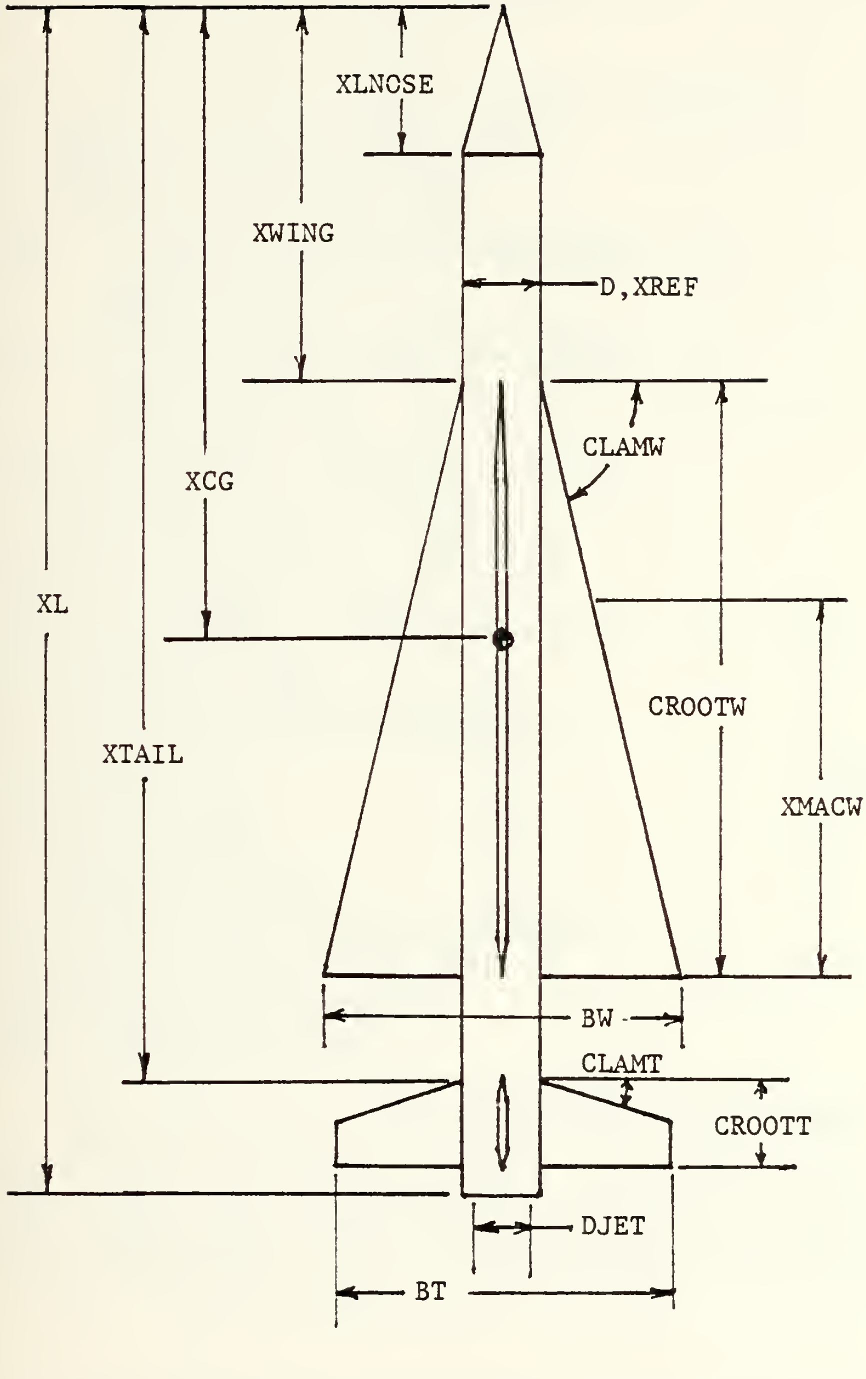


Figure (V-1). Tail control missile as used in Example V-A

```
THE FOLLOWING TABLE CONTAINS THE INPUT DATA FOR

EXAMPLE V-A.  TAIL CONTROL MISSILE

 1) (ICSC) CONTROL CONSTANT; 1=TAIL, 2=WING, 3=CANARD:          1
 2) (INOSE) NOSE SHAPE; 1=ELLIPSE, 2=OGIVE, 3=CONE;             3
 3) (IDT) NUMBER OF CONTROL DEFLECTIONS:                        5
 4) (IM) NUMBER OF MACH NUMBERS:                                1
 5) (IAL) NUMBER OF ANGLES OF ATTACK:                          11
 6) (NBODY) NUMBER OF CONFIGURATIONS:                           1
 7) (ISWPW) 1=NON-DELTA WING, 2=DELTA WING:                     2
 8) (IAFBW) 0=NO BODY AFTER WING, 1=BODY AFTER WING:            1
 9) (ISWEPW) WING SWEEP CONSTANT (IF DELTA=0)
            0=UNSWEPT LEADING EDGE, 1=SWEPT LEADING EDGE:       0
10) (NWING) NUMBER OF WINGS:                                    4
11) (ISWPT) 1=NON-DELTA TAIL, 2=DELTA TAIL:                     1
12) (IAFBT) 0=NO BODY AFTER TAIL,1=BODY AFTER TAIL:             1
13) (ISWEPT) TAIL SWEEP CONSTANT (IF DELTA=0)
            0=UNSWEPT LEADING EDGE, 1=SWEPT LEADING EDGE:       1
14) (NTAIL) NUMBER OF TAILS:                                    4
15) (XLAMW) TIP-TO-CHORD RATIO OF WING:                         0.0
16) (CLAMW) WING LEADING EDGE SWEEP(DEGREES):                  77.000
17) (BW) WING SPAN, INCLUDING BODY:                             1.800
18) (CROOTW) WING ROOT CHORD (AT BODY JUNCTION):                2.960
19) (SW) EXPOSED WING AREA (TWO PANELS):                        2.072
20) (XMACW) WING MEAN GEOMETRIC CHORD:                          1.973
21) (XWING) DISTANCE FROM NOSE TO WING LE:                      1.902
22) (TOVCW) WING THICKNESS TO CHORD RATIO:                      0.030
23) (XLAMT) TIP-TO-CHORD RATIO OF TAIL:                         0.609
24) (CLAMT) TAIL LEADING EDGE SWEEP (DEGREES):                 15.000
25) (BT) TAIL SPAN, INCLUDING BODY:                             1.700
26) (CROOTT) TAIL ROOT CHORD:                                   0.400
27) (ST) EXPOSED TAIL AREA (TWO PANELS):                        0.418
28) (XMACT) TAIL MEAN GEOMETRIC CHORD:                          0.328
29) (XTAIL) DISTANCE FROM NOSE TO TAIL LE:                      5.420
30) (TOVCT) TAIL THICKNESS TO CHORD RATIO:                      0.076
31) (HT) ALTITUDE:                                          30000.000
32) (D) BODY DIAMETER:                                          0.400
33) (XL) MISSILE LENGTH:                                        6.000
34) (XLNOSE) NOSE LENGTH:                                       0.750
35) (XCG) DISTANCE TO CG LOCATION FROM NOSE:                    3.200
36) (AREA) REFERENCE AREA:                                      0.127
37) (XREF) REFERENCE LENGTH:                                    0.400
38) (ENGINE) ENGINE; 0.0=TURBOFAN, 1.0=ROCKET:                  1.0
39) (ENLET) INLET; 0.0=FLUSH, 1.0=EXTENDED:                     0.0
40) (BETA) BOAT-TAIL ANGLE (DEGREES):                           0.0
41) (DBASE) BASE DIAMETER:                                      0.400
42) (DJET) NOZZLE EXIT DIAMETER:                                0.250
43) (XLABCD) BOAT-TAIL LENGTH:                                  0.0
44) (CDPRCT) PROTUBERANCE DRAG:                                 0.0

MACH   2.000 0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
       0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

DELTA   0.0   4.00  8.00 12.00 16.00  0.0   0.0   0.0   0.0   0.0   0.0
        0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

ALPHA   0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00
        0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
```

Table (V-1). Input data for Example V-A

```
MACH   2.0000
DELTA=   0.0
AL   CLTCT CDTOT   CLWP   CLBW   CLTP   CLBT    CLB    CDI   CNWP   CNTP   CLTD   CDTO     CN     CA   XCPW   XCPT   XCPB    XCP     CM

 0.   0.00  0.92   0.00   0.00  -0.00   0.00   0.00   0.00   0.00  -0.00   0.00   0.00   0.00   0.92   3.90   5.71   0.00   3.72  -0.00
 1.   0.73  0.93   0.61   0.10  -0.03   0.03   0.03   0.01   0.62  -0.03   0.00   0.00   0.75   0.92   3.90   5.71   0.51   3.69  -0.91
 2.   1.52  0.97   1.24   0.19  -0.04   0.05   0.08   0.04   1.25  -0.04   0.00   0.00   1.55   0.91   3.90   5.71   0.87   3.72  -2.01
 3.   2.36  1.03   1.88   0.29  -0.02   0.08   0.14   0.10   1.90  -0.02   0.00   0.00   2.40   0.90   3.90   5.71   1.15   3.75  -3.30
 4.   3.25  1.12   2.53   0.38   0.03   0.10   0.21   0.20   2.55   0.04   0.00   0.00   3.30   0.89   3.90   5.71   1.37   3.78  -4.79
 5.   4.18  1.26   3.19   0.48   0.10   0.13   0.29   0.33   3.22   0.11   0.00   0.00   4.25   0.89   3.90   5.71   1.55   3.81  -6.45
 6.   5.16  1.43   3.86   0.57   0.19   0.15   0.39   0.51   3.90   0.20   0.00   0.00   5.25   0.88   3.90   5.71   1.70   3.83  -8.24
 7.   6.18  1.66   4.54   0.66   0.30   0.18   0.50   0.73   4.59   0.32   0.00   0.00   6.28   0.89   3.90   5.71   1.83   3.85 -10.14
 8.   7.23  1.93   5.23   0.75   0.42   0.20   0.62   1.01   5.29   0.44   0.00   0.00   7.35   0.91   3.90   5.71   1.93   3.86 -12.14
 9.   8.31  2.26   5.92   0.85   0.56   0.22   0.76   1.34   5.99   0.57   0.00   0.00   8.44   0.93   3.90   5.71   2.03   3.87 -14.22
10.   9.41  2.65   6.62   0.94   0.70   0.25   0.91   1.72   6.71   0.72   0.00   0.00   9.57   0.97   3.90   5.71   2.11   3.88 -16.36
CDINL=0.0      CDAFT=0.0      CDPROT=0.0      CDOB=0.3326
CDOW=0.3042 CDOT=0.1489 CDMISC=0.0752 CDOWBT=0.9230

MACH   2.0000
DELTA=   4.00
AL   CLTCT CDTOT   CLWP   CLBW   CLTP   CLBT    CLB    CDI   CNWP   CNTP   CLTD   CDTO     CN     CA   XCPW   XCPT   XCPB    XCP     CM

 0.   0.79  0.94   0.00   0.00   0.60   0.19   0.00   0.01   0.00   0.60   0.59   0.01   0.79   0.94   3.90   5.71   0.00   5.78  -5.12
 1.   1.54  0.97   0.61   0.10   0.58   0.21   0.03   0.04   0.62   0.58   0.59   0.01   1.55   0.95   3.90   5.71   0.51   4.77  -6.09
 2.   2.33  1.03   1.24   0.19   0.58   0.24   0.08   0.10   1.25   0.59   0.59   0.01   2.36   0.95   3.90   5.71   0.87   4.43  -7.24
 3.   3.18  1.12   1.88   0.29   0.61   0.26   0.14   0.19   1.90   0.62   0.59   0.01   3.22   0.95   3.90   5.71   1.15   4.27  -8.60
 4.   4.08  1.24   2.53   0.38   0.67   0.29   0.21   0.31   2.55   0.68   0.59   0.01   4.13   0.95   3.90   5.71   1.37   4.18 -10.13
 5.   5.02  1.40   3.19   0.48   0.75   0.31   0.29   0.47   3.22   0.76   0.59   0.01   5.09   0.96   3.90   5.71   1.55   4.13 -11.42
 6.   6.00  1.61   3.86   0.57   0.85   0.34   0.39   0.68   3.90   0.86   0.59   0.01   6.09   0.97   3.90   5.71   1.70   4.10 -13.64
 7.   7.02  1.86   4.54   0.66   0.96   0.36   0.50   0.93   4.59   0.97   0.58   0.01   7.12   0.99   3.90   5.71   1.83   4.07 -15.56
 8.   8.09  2.17   5.23   0.75   1.09   0.38   0.62   1.24   5.29   1.10   0.58   0.01   8.19   1.02   3.90   5.71   1.93   4.06 -17.57
 9.   9.16  2.53   5.92   0.85   1.22   0.41   0.76   1.60   5.99   1.24   0.58   0.01   9.29   1.07   3.90   5.71   2.03   4.05 -19.66
10.  10.27  2.95   6.62   0.94   1.37   0.43   0.91   2.02   6.71   1.38   0.58   0.01  10.42   1.12   3.90   5.71   2.11   4.04 -21.80
CDINL=0.0      CDAFT=0.0      CDPROT=0.0      CDOB=0.3326
CDOW=0.3042 CDOT=0.1499 CDMISC=0.0752 CDOWBT=0.9230

MACH   2.0000
DELTA=   8.00
AL   CLTCT CDTOT   CLWP   CLBW   CLTP   CLBT    CLB    CDI   CNWP   CNTP   CLTD   CDTD     CN     CA   XCPW   XCPT   XCPB    XCP     CM

 0.   1.59  1.00   0.00   0.00   1.22   0.37   0.00   0.05   0.00   1.22   1.18   0.03   1.59   1.00   3.90   5.71   0.00   5.78 -10.27
 1.   2.34  1.05   0.61   0.10   1.20   0.40   0.03   0.10   0.62   1.21   1.17   0.03   2.36   1.01   3.90   5.71   0.51   5.11 -11.29
 2.   3.15  1.13   1.24   0.19   1.21   0.42   0.08   0.18   1.25   1.22   1.17   0.03   3.17   1.02   3.90   5.71   0.87   4.77 -12.49
 3.   4.00  1.24   1.88   0.29   1.25   0.45   0.14   0.29   1.90   1.26   1.17   0.03   4.04   1.03   3.90   5.71   1.15   4.57 -13.89
 4.   4.91  1.39   2.53   0.38   1.31   0.47   0.21   0.44   2.55   1.32   1.16   0.03   4.96   1.04   3.90   5.71   1.37   4.45 -15.45
 5.   5.85  1.58   3.19   0.48   1.40   0.49   0.29   0.63   3.22   1.41   1.16   0.03   5.92   1.07   3.90   5.71   1.55   4.36 -17.16
 6.   6.84  1.82   3.86   0.57   1.50   0.52   0.39   0.87   3.90   1.51   1.15   0.03   6.92   1.09   3.90   5.71   1.70   4.30 -18.99
 7.   7.86  2.10   4.54   0.66   1.62   0.54   0.50   1.15   4.59   1.63   1.15   0.03   7.95   1.13   3.90   5.71   1.83   4.25 -20.92
 8.   8.91  2.44   5.23   0.75   1.74   0.56   0.62   1.49   5.29   1.76   1.14   0.03   9.02   1.18   3.90   5.71   1.93   4.22 -22.93
 9.   9.99  2.84   5.92   0.85   1.88   0.59   0.76   1.89   5.99   1.89   1.14   0.03  10.12   1.24   3.90   5.71   2.03   4.19 -25.00
10.  11.10  3.29   6.62   0.94   2.03   0.61   0.91   2.34   6.71   2.04   1.13   0.03  11.25   1.31   3.90   5.71   2.11   4.16 -27.13
CDINL=0.0      CDAFT=0.0      CDPROT=0.0      CDOB=0.3326
CDOW=0.3042 CDOT=0.1489 CDMISC=0.0752 CDOWBT=0.9230
```

Table (V-2). Output of Example V-A

```
MACH   2.0000
DELTA=  12.00
AL   CLTOT CDTOT   CLWP    CLBW    CLTP    CLBT     CLB     CDI    CNWP   CNTP   CLTD   CDTD     CN      CA    XCPW   XCPT   XCPB    XCP     CM

 0.   2.38  1.08   0.00    0.00    1.83    0.55    0.00    0.10    0.00   1.83   1.74   0.06   2.38   1.08   3.90   5.71   0.00   5.78  -15.36
 1.   3.14  1.16   0.61    0.10    1.82    0.58    0.03    0.18    0.62   1.82   1.73   0.06   3.15   1.10   3.90   5.71   0.51   5.28  -15.41
 2.   3.95  1.26   1.24    0.19    1.84    0.60    0.08    0.28    1.25   1.84   1.72   0.06   3.98   1.12   3.90   5.71   0.87   4.98  -17.65
 3.   4.81  1.40   1.88    0.29    1.88    0.62    0.14    0.42    1.90   1.89   1.71   0.06   4.85   1.15   3.90   5.71   1.15   4.77  -19.07
 4.   5.71  1.57   2.53    0.38    1.95    0.64    0.21    0.59    2.55   1.96   1.71   0.06   5.77   1.17   3.90   5.71   1.37   4.63  -20.65
 5.   6.66  1.79   3.19    0.48    2.03    0.67    0.29    0.81    3.22   2.05   1.70   0.06   6.73   1.20   3.90   5.71   1.55   4.53  -22.36
 6.   7.65  2.06   3.86    0.57    2.14    0.69    0.39    1.08    3.90   2.15   1.69   0.06   7.73   1.25   3.90   5.71   1.70   4.45  -24.18
 7.   8.67  2.37   4.54    0.66    2.25    0.71    0.50    1.39    4.59   2.27   1.68   0.06   8.76   1.30   3.90   5.71   1.83   4.39  -26.10
 8.   9.72  2.74   5.23    0.75    2.38    0.73    0.62    1.76    5.29   2.39   1.67   0.06   9.83   1.36   3.90   5.71   1.93   4.34  -28.09
 9.  10.80  3.16   5.92    0.85    2.52    0.75    0.76    2.18    5.99   2.53   1.66   0.05  10.92   1.43   3.90   5.71   2.03   4.30  -30.14
10.  11.90  3.65   6.62    0.94    2.66    0.77    0.91    2.67    6.71   2.67   1.65   0.05  12.04   1.52   3.90   5.71   2.11   4.27  -32.23
CDINL=0.0      CDAFT=0.0      CDPROT=0.0      CDOB=0.3326
CDOW=0.3042 CDOT=0.1489 CDMISC=0.0752 CDOWBT=0.9230

MACH   2.0000
DELTA=  16.00
AL   CLTOT CDTOT   CLWP    CLBW    CLTP    CLBT     CLB     CDI    CNWP   CNTP   CLTD   CDTD     CN      CA    XCPW   XCPT   XCPB    XCP     CM

 0.   3.15  1.20   0.00    0.00    2.43    0.72    0.00    0.18    0.00   2.43   2.26   0.10   3.15   1.20   3.90   5.71   0.00   5.78  -20.26
 1.   3.91  1.30   0.61    0.10    2.42    0.74    0.03    0.27    0.62   2.43   2.25   0.10   3.92   1.23   3.90   5.71   0.51   5.38  -21.34
 2.   4.72  1.42   1.24    0.19    2.44    0.76    0.08    0.40    1.25   2.45   2.24   0.10   4.75   1.26   3.90   5.71   0.87   5.10  -22.59
 3.   5.58  1.58   1.88    0.29    2.49    0.78    0.14    0.56    1.90   2.50   2.22   0.10   5.62   1.29   3.90   5.71   1.15   4.91  -24.02
 4.   6.48  1.78   2.53    0.38    2.56    0.80    0.21    0.76    2.55   2.57   2.21   0.10   6.54   1.32   3.90   5.71   1.37   4.77  -25.60
 5.   7.43  2.02   3.19    0.48    2.64    0.82    0.29    1.00    3.22   2.66   2.20   0.10   7.50   1.37   3.90   5.71   1.55   4.66  -27.29
 6.   8.41  2.31   3.86    0.57    2.74    0.84    0.39    1.29    3.90   2.76   2.18   0.10   8.49   1.42   3.90   5.71   1.70   4.57  -29.10
 7.   9.43  2.65   4.54    0.66    2.86    0.86    0.50    1.64    4.59   2.88   2.17   0.09   9.52   1.48   3.90   5.71   1.83   4.50  -30.98
 8.  10.47  3.05   5.23    0.75    2.98    0.88    0.62    2.03    5.29   3.00   2.15   0.09  10.58   1.56   3.90   5.71   1.93   4.45  -32.94
 9.  11.54  3.50   5.92    0.85    3.12    0.90    0.76    2.48    5.99   3.13   2.13   0.09  11.67   1.65   3.90   5.71   2.03   4.40  -34.95
10.  12.64  4.01   6.62    0.94    3.26    0.92    0.91    2.99    6.71   3.27   2.11   0.09  12.79   1.75   3.90   5.71   2.11   4.36  -37.00
CDINL=0.0      CDAFT=0.0      CDPROT=0.0      CDOB=0.3326
CDOW=0.3042 CDOT=0.1489 CDMISC=0.0752 CDOWBT=0.9230
```

Table (V-2). (Continued)

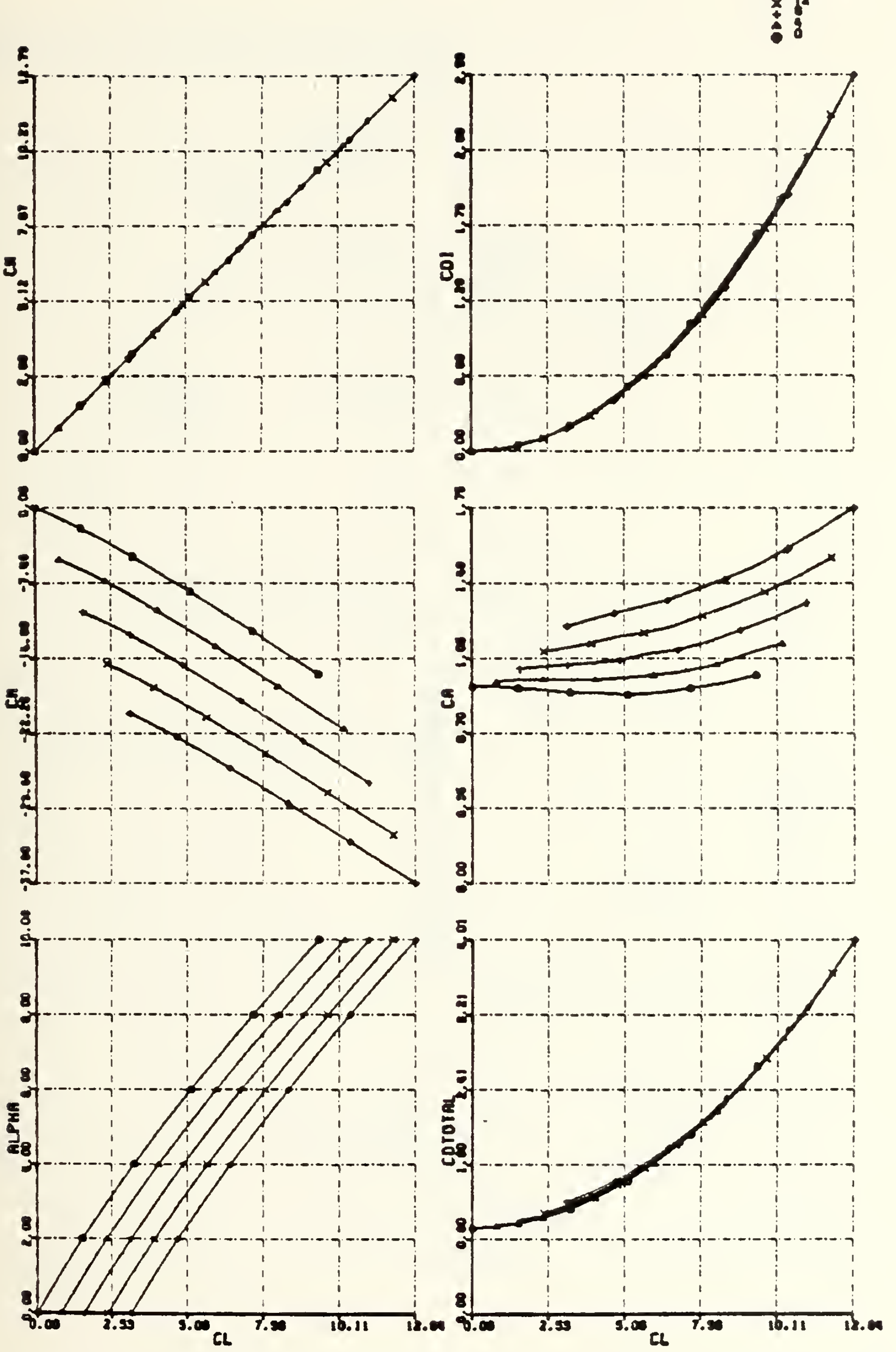


Figure (V-2). Output data plot for Example V-A

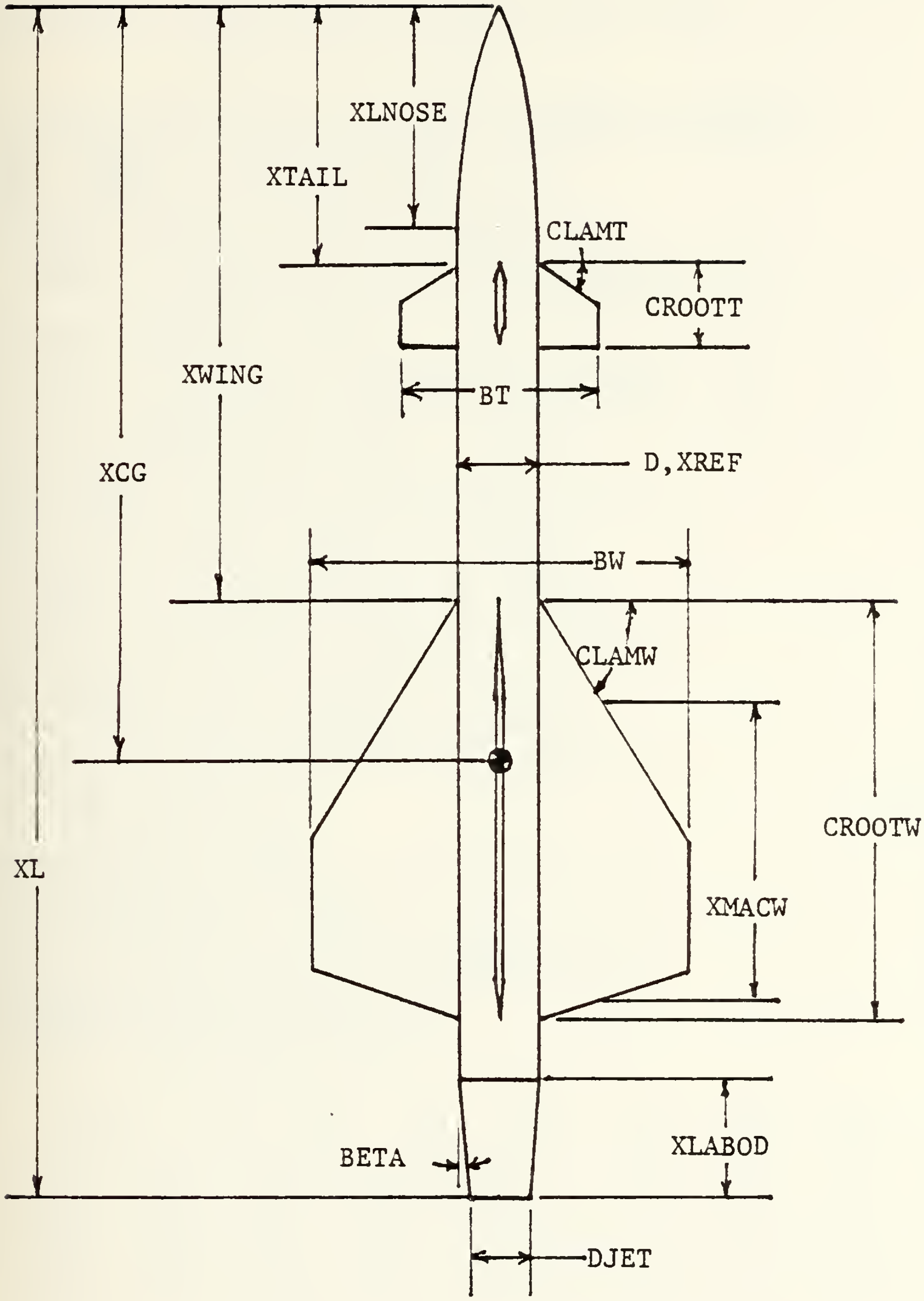


Figure (V-3). Canard control missile for Example V-B

```
THE FOLLOWING TABLE CONTAINS THE INPUT DATA FOR

EXAMPLE V-B.  CANARD CONTROL MISSILE

 1) (ICSC) CONTROL CONSTANT; 1=TAIL, 2=WING, 3=CANARD:                 3
 2) (INOSE) NOSE SHAPE; 1=ELLIPSE, 2=OGIVE, 3=CONE;                    2
 3) (IDT) NUMBER OF CONTROL DEFLECTIONS:                               5
 4) (IM) NUMBER OF MACH NUMBERS:                                       1
 5) (IAL) NUMBER OF ANGLES OF ATTACK:                                 11
 6) (NBODY) NUMBER OF CONFIGURATIONS:                                  1
 7) (ISWPW) 1=NON-DELTA WING, 2=DELTA WING:                            1
 8) (IAFBW) 0=NO BODY AFTER WING, 1=BODY AFTER WING:                   1
 9) (ISWEPW) WING SWEEP CONSTANT (IF DELTA=0)
          0=UNSWEPT LEADING EDGE, 1=SWEPT LEADING EDGE:                1
10). (NWING) NUMBER OF WINGS:                                          4
11) (ISWPT) 1=NON-DELTA TAIL, 2=DELTA TAIL:                            1
12) (IAFBT) 0=NO BODY AFTER TAIL,1=BODY AFTER TAIL:                    1
13) (ISWEPT) TAIL SWEEP CONSTANT (IF DELTA=0)
          0=UNSWEPT LEADING EDGE, 1=SWEPT LEADING EDGE:                1
14) (NTAIL) NUMBER OF TAILS:                                           4
15) (XLAMW) TIP-TO-CHORD RATIO OF WING:                              0.314
16) (CLAMW) WING LEADING EDGE SWEEP(DEGREES):                       57.500
17) (BW) WING SPAN, INCLUDING BODY:                                  3.600
18) (CRCCTW) WING ROOT CHORD (AT BODY JUNCTION):                     4.140
19) (SW) EXPOSED WING AREA (TWO PANELS):                             8.070
20) (XMACW) WING MEAN GEOMETRIC CHORD:                               2.522
21) (XWING) DISTANCE FROM NOSE TO WING LE:                           6.060
22) (TOVCW) WING THICKNESS TO CHORD RATIO:                           0.050
23) (XLAMT) TIP-TO-CHORD RATIO OF TAIL:                              0.541
24) (CLAMT) TAIL LEADING EDGE SWEEP (DEGREES):                      32.000
25) (BT) TAIL SPAN, INCLUDING BODY:                                  2.000
26) (CRCCTT) TAIL ROOT CHORD:                                        0.614
27) (ST) EXPOSED TAIL AREA (TWO PANELS):                             0.568
28) (XMACT) TAIL MEAN GEOMETRIC CHORD:                               0.473
29) (XTAIL) DISTANCE FROM NOSE TO TAIL LE:                           2.700
30) (TOVCT) TAIL THICKNESS TO CHORD RATIO:                           0.085
31) (HT) ALTITUDE:                                               70000.000
32) (D) BODY DIAMETER:                                               0.800
33) (XL) MISSILE LENGTH:                                            12.000
34) (XLNOSE) NOSE LENGTH:                                            2.200
35) (XCG) DISTANCE TO CG LOCATION FROM NOSE:                         7.600
36) (AREA) REFERENCE AREA:                                           0.503
37) (XREF) REFERENCE LENGTH:                                         0.800
38) (ENGINE) ENGINE; 0.0=TURBOFAN, 1.0=ROCKET:                       1.0
39) (ENLET) INLET; 0.0=FLUSH, 1.0=EXTENDED:                          0.0
40) (BETA) BOAT-TAIL ANGLE (DEGREES):                                5.000
41) (DBASE) BASE DIAMETER:                                           0.600
42) (DJET) NOZZLE EXIT DIAMETER:                                     0.600
43) (XLABCD) BOAT-TAIL LENGTH:                                       1.200
44) (CDPRCT) PROTUBERANCE DRAG:                                      0.0

MACH   3.500 0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
       0.0   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

DELTA   0.0   4.00   8.00  12.00  16.00   0.0    0.0    0.0    0.0    0.0    0.0
        0.0   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

ALPHA   0.0   1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00
        0.0   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
```

Table (V-3). Input data for Example V-B

```
MACH   3.5000
DELTA=   0.0
AL   CLTOT CDTOT   CLWP   CLBW   CLTP   CLBT    CLB    CDI   CNWP   CNTP   CLTD   CDTD     CN     CA   XCPW   XCPT   XCPB    XCP     CM

 0.   0.00  0.49   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.49   9.13   3.20   0.00   7.84  -0.00
 1.   0.49  0.50   0.32   0.08   0.05   0.01   0.04   0.00   0.33   0.05   0.00   0.00   0.50   0.49   9.13   3.20   1.02   7.90  -0.19
 2.   1.03  0.51   0.68   0.15   0.10   0.01   0.09   0.02   0.69   0.10   0.00   0.00   1.05   0.48   9.13   3.20   1.76   7.91  -0.40
 3.   1.61  0.55   1.06   0.23   0.15   0.02   0.15   0.05   1.08   0.15   0.00   0.00   1.63   0.46   9.13   3.20   2.33   7.91  -0.64
 4.   2.23  0.59   1.46   0.30   0.20   0.03   0.23   0.10   1.49   0.21   0.00   0.00   2.26   0.44   9.13   3.20   2.79   7.92  -0.90
 5.   2.88  0.66   1.89   0.37   0.25   0.04   0.33   0.17   1.92   0.26   0.00   0.00   2.92   0.41   9.13   3.20   3.17   7.92  -1.18
 6.   3.57  0.76   2.34   0.45   0.30   0.04   0.43   0.26   2.37   0.31   0.00   0.00   3.62   0.38   9.13   3.20   3.49   7.92  -1.46
 7.   4.30  0.88   2.81   0.52   0.36   0.05   0.56   0.38   2.85   0.37   0.00   0.00   4.36   0.35   9.13   3.20   3.76   7.92  -1.75
 8.   5.07  1.03   3.30   0.59   0.41   0.06   0.71   0.54   3.34   0.42   0.00   0.00   5.13   0.31   9.13   3.20   4.01   7.92  -2.04
 9.   5.88  1.22   3.81   0.67   0.47   0.05   0.87   0.73   3.85   0.48   0.00   0.00   5.94   0.29   9.13   3.20   4.22   7.91  -2.32
10.   6.72  1.45   4.33   0.74   0.52   0.07   1.07   0.96   4.38   0.53   0.00   0.00   6.80   0.26   9.13   3.20   4.42   7.90  -2.59
CDINL=0.0     CDAFT=0.0      CDPROT=0.0     CDOB=0.0485
CDOW=0.3331 CDOT=0.1125 CDMISC=0.0527 CDOWBT=0.4942

MACH   3.5000
DELTA=   4.00
AL   CLTOT CDTOT   CLWP   CLBW   CLTP   CLBT    CLB    CDI   CNWP   CNTP   CLTD   CDTD     CN     CA   XCPW   XCPT   XCPB    XCP     CM

 0.   0.20  0.50   0.00   0.00   0.13   0.07   0.00   0.00   0.00   0.13   0.12   0.00   0.20   0.50   9.13   3.20   0.00   3.53   1.01
 1.   0.70  0.50   0.32   0.08   0.18   0.08   0.04   0.01   0.33   0.18   0.12   0.00   0.70   0.49   9.13   3.20   1.02   6.63   0.85
 2.   1.24  0.52   0.68   0.15   0.24   0.08   0.09   0.03   0.69   0.24   0.12   0.00   1.25   0.48   9.13   3.20   1.76   7.18   0.66
 3.   1.82  0.56   1.06   0.23   0.29   0.09   0.15   0.06   1.07   0.30   0.12   0.00   1.84   0.46   9.13   3.20   2.33   7.41   0.44
 4.   2.44  0.61   1.46   0.30   0.34   0.10   0.23   0.12   1.48   0.35   0.12   0.00   2.47   0.44   9.13   3.20   2.79   7.54   0.20
 5.   3.10  0.69   1.89   0.37   0.40   0.10   0.33   0.19   1.92   0.41   0.12   0.00   3.14   0.41   9.13   3.20   3.17   7.61  -0.05
 6.   3.79  0.78   2.34   0.45   0.46   0.11   0.43   0.29   2.37   0.47   0.12   0.00   3.84   0.38   9.13   3.20   3.49   7.67  -0.32
 7.   4.52  0.91   2.81   0.52   0.51   0.12   0.56   0.42   2.85   0.53   0.12   0.00   4.59   0.35   9.13   3.20   3.76   7.70  -0.59
 8.   5.29  1.07   3.30   0.59   0.57   0.13   0.71   0.58   3.34   0.58   0.12   0.00   5.35   0.32   9.13   3.20   4.01   7.73  -0.86
 9.   6.10  1.27   3.80   0.67   0.63   0.13   0.87   0.77   3.85   0.64   0.12   0.00   6.17   0.30   9.13   3.20   4.22   7.75  -1.13
10.   6.95  1.51   4.32   0.74   0.69   0.14   1.07   1.02   4.37   0.70   0.12   0.00   7.03   0.28   9.13   3.20   4.42   7.76  -1.39
CDINL=0.0     CDAFT=0.0      CDPROT=0.0     CDOB=0.0485
CDOW=0.3331 CDOT=0.1125 CDMISC=0.0527 CDOWBT=0.4942

MACH   3.5000
DELTA=   8.00
AL   CLTOT CDTOT   CLWP   CLBW   CLTP   CLBT    CLB    CDI   CNWP   CNTP   CLTD   CDTD     CN     CA   XCPW   XCPT   XCPB    XCP     CM

 0.   0.41  0.50   0.00   0.00   0.27   0.14   0.00   0.00   0.00   0.27   0.24   0.00   0.41   0.50   9.13   3.20   0.00   3.52   2.10
 1.   0.91  0.51   0.32   0.08   0.33   0.14   0.04   0.02   0.33   0.33   0.24   0.00   0.92   0.50   9.13   3.20   1.02   5.39   1.96
 2.   1.45  0.54   0.67   0.15   0.39   0.15   0.09   0.04   0.69   0.39   0.24   0.00   1.47   0.49   9.13   3.20   1.76   6.63   1.78
 3.   2.04  0.58   1.05   0.23   0.44   0.16   0.15   0.08   1.07   0.45   0.24   0.00   2.06   0.47   9.13   3.20   2.33   6.99   1.58
 4.   2.66  0.63   1.46   0.30   0.50   0.16   0.23   0.14   1.48   0.51   0.24   0.00   2.69   0.45   9.13   3.20   2.79   7.20   1.36
 5.   3.32  0.71   1.89   0.37   0.56   0.17   0.33   0.22   1.91   0.57   0.24   0.00   3.36   0.42   9.13   3.20   3.17   7.33   1.12
 6.   4.02  0.82   2.34   0.45   0.62   0.18   0.43   0.32   2.37   0.63   0.24   0.00   4.06   0.39   9.13   3.20   3.49   7.43   0.87
 7.   4.75  0.95   2.81   0.52   0.68   0.18   0.56   0.45   2.84   0.69   0.23   0.00   4.81   0.37   9.13   3.20   3.76   7.50   0.61
 8.   5.52  1.12   3.29   0.59   0.74   0.19   0.71   0.62   3.33   0.75   0.23   0.00   5.58   0.34   9.13   3.20   4.01   7.55   0.35
 9.   6.34  1.32   3.80   0.67   0.80   0.20   0.87   0.83   3.84   0.81   0.23   0.00   6.40   0.32   9.13   3.20   4.22   7.59   0.09
10.   7.19  1.57   4.32   0.74   0.86   0.20   1.07   1.07   4.37   0.87   0.23   0.00   7.26   0.30   9.13   3.20   4.42   7.62  -0.16
CDINL=0.0     CDAFT=0.0      CDPROT=0.0     CDOB=0.0485
CDOW=0.3331 CDOT=0.1125 CDMISC=0.0527 CDOWBT=0.4942
```

Table (V-4). Output of Example V-B

```
MACH   3.5000
DELTA= 12.00
AL  CLTOT CDTOT  CLWP  CLBW  CLTP  CLBT   CLB   CDI  CNWP  CNTP  CLTD  CDTD    CN    CA  XCPW  XCPT  XCPB   XCP    CM

 0.   0.63  0.51  0.00  0.00  0.43  0.20  0.00  0.01  0.00  0.43  0.35  0.01  0.63  0.51  9.13  3.20  0.00  3.50  3.23
 1.   1.13  0.52  0.32  0.08  0.49  0.21  0.04  0.02  0.33  0.49  0.35  0.01  1.14  0.50  9.13  3.20  1.02  5.42  3.11
 2.   1.68  0.55  0.67  0.15  0.55  0.22  0.09  0.05  0.68  0.55  0.35  0.01  1.69  0.49  9.13  3.20  1.76  6.21  2.95
 3.   2.26  0.60  1.05  0.23  0.61  0.22  0.15  0.10  1.07  0.61  0.35  0.01  2.29  0.48  9.13  3.20  2.33  6.63  2.76
 4.   2.89  0.66  1.46  0.30  0.67  0.23  0.23  0.16  1.48  0.68  0.35  0.01  2.92  0.46  9.13  3.20  2.79  6.90  2.55
 5.   3.55  0.74  1.88  0.37  0.73  0.23  0.33  0.24  1.91  0.74  0.35  0.01  3.59  0.43  9.13  3.20  3.17  7.08  2.32
 6.   4.25  0.86  2.33  0.45  0.79  0.24  0.43  0.35  2.37  0.80  0.34  0.01  4.29  0.41  9.13  3.20  3.49  7.21  2.08
 7.   4.93  0.99  2.80  0.52  0.85  0.25  0.56  0.49  2.84  0.86  0.34  0.01  5.03  0.38  9.13  3.20  3.76  7.31  1.82
 8.   5.75  1.17  3.29  0.59  0.91  0.25  0.71  0.67  3.33  0.93  0.34  0.01  5.81  0.36  9.13  3.20  4.01  7.38  1.57
 9.   6.57  1.38  3.80  0.67  0.97  0.26  0.87  0.88  3.84  0.99  0.34  0.01  6.63  0.33  9.13  3.20  4.22  7.44  1.31
10.   7.42  1.63  4.32  0.74  1.03  0.26  1.07  1.13  4.37  1.05  0.34  0.01  7.49  0.32  9.13  3.20  4.42  7.49  1.07
CDINL=0.0     CDAFT=0.0     CDPROT=0.0     CDOB=0.0485
CDOW=0.3331 CDOT=0.1125 CDMISC=0.0527 CDOWBT=0.4942

MACH   3.5000
DELTA= 16.00
AL  CLTOT CDTOT  CLWP  CLBW  CLTP  CLBT   CLB   CDI  CNWP  CNTP  CLTD  CDTD    CN    CA  XCPW  XCPT  XCPB   XCP    CM

 0.   0.85  0.52  0.00  0.00  0.59  0.26  0.00  0.01  0.00  0.59  0.46  0.01  0.85  0.52  9.13  3.20  0.00  3.49  4.39
 1.   1.35  0.54  0.32  0.08  0.65  0.27  0.04  0.03  0.33  0.65  0.46  0.01  1.36  0.52  9.13  3.20  1.02  5.09  4.27
 2.   1.90  0.57  0.67  0.15  0.71  0.28  0.09  0.07  0.68  0.72  0.46  0.01  1.92  0.51  9.13  3.20  1.76  5.88  4.12
 3.   2.48  0.62  1.05  0.23  0.77  0.28  0.15  0.11  1.07  0.78  0.45  0.01  2.51  0.49  9.13  3.20  2.33  6.34  3.94
 4.   3.11  0.69  1.45  0.30  0.84  0.29  0.23  0.18  1.48  0.84  0.45  0.01  3.14  0.47  9.13  3.20  2.79  6.65  3.74
 5.   3.77  0.78  1.88  0.37  0.90  0.29  0.33  0.27  1.91  0.91  0.45  0.01  3.81  0.45  9.13  3.20  3.17  6.86  3.51
 6.   4.47  0.89  2.33  0.45  0.96  0.30  0.43  0.39  2.36  0.97  0.45  0.01  4.52  0.42  9.13  3.20  3.49  7.02  3.27
 7.   5.21  1.04  2.80  0.52  1.02  0.30  0.56  0.53  2.84  1.04  0.44  0.01  5.26  0.40  9.13  3.20  3.76  7.14  3.02
 8.   5.98  1.22  3.29  0.59  1.08  0.31  0.71  0.71  3.33  1.10  0.44  0.01  6.04  0.37  9.13  3.20  4.01  7.23  2.76
 9.   6.79  1.44  3.79  0.67  1.14  0.31  0.87  0.93  3.84  1.16  0.44  0.01  6.86  0.36  9.13  3.20  4.22  7.31  2.50
10.   7.64  1.70  4.31  0.74  1.21  0.32  1.07  1.19  4.36  1.22  0.43  0.01  7.71  0.34  9.13  3.20  4.42  7.37  2.25
CDINL=0.0     CDAFT=0.0     CDPROT=0.0     CDOB=0.0485
CDOW=0.3331 CDOT=0.1125 CDMISC=0.0527 CDOWBT=0.4942
```

Table (V-4). (Continued)

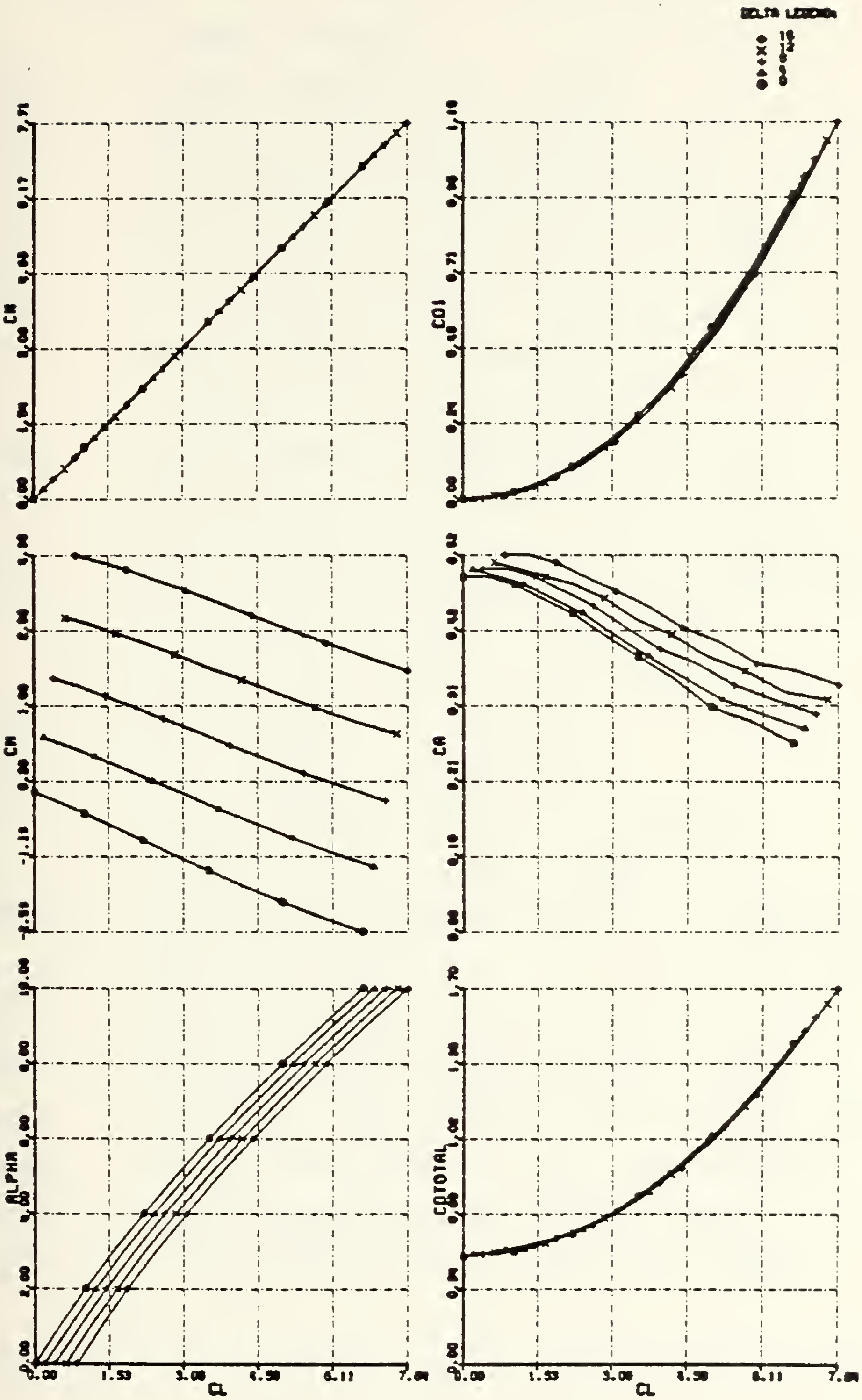


Figure (V-4). Output data plot for Example V-B

Table (V-5). Output variables of LAERO1

| | |
|---|---|
| AL | Angle of attack |
| CLTOT | Total coefficient of lift |
| CDTOT | Total coefficient of drag |
| CLWP | Wing panel coefficient of lift |
| CLBW | Additional lift on body due to wing |
| CLTP | Tail panel coefficient of lift |
| CLBT | Additional lift on body due to tail |
| CLB | Body alone lift coefficient |
| CDI | Induced drag coefficient |
| CNWP | Wing panel normal force coefficient |
| CNTP | Tail panel normal force coefficient |
| CLTD | Lift coefficient due to tail deflection |
| CDTD | Drag coefficient due to tail deflection |
| CN | Total normal force coefficient |
| CA | Total axial force coefficient |
| XCPW | Wing center of pressure |
| XCPT | Tail center of pressure |
| XCP | Total missile center of pressure |
| CM | Total pitching moment about C.G. |
| CDOWBT | Zero lift drag coefficient of wing-body-tail combination |
| CDMISC | Miscellaneous zero lift drag coefficient |
| CDOT | Zero lift drag coefficient of tail |
| CDOW | Zero lift drag coefficient of wing |
| CDOB | Zero lift drag coefficient of body alone |
| CDPROT | Drag coefficient of body protrusions |
| CDINL | Drag coefficient of engine inlet |
| CDAFT | Drag coefficient of boattail region |

# VI. CONCLUSIONS AND RECOMMENDATIONS

There are many topics which may be the subjects of follow on work contained within this thesis. Although the four programs have been installed on the IBM 370 computer system, these four alone do not fully satisfy the original goal of this work: Provide a computer supplement to the Tactical Missile Conceptual Design handbook. Numerous additional focal algorithms are utilized in the design handbook which deserve the attention of a programmer. Of immediate interest are the areas concerning radar or infrared guidance systems, baseline configuration modelling and weight distribution, and initial control and lifting surface design. Each of these topics can be programmed to provide missile design students interactive learning tools when coupled with the design handbook.

The most urgent follow on work to this thesis is the restoration of the program LAERO1 to a reliable, useful program. The program was modified and set up on the IBM 370 computer system during the period immediately following the system's installation at the Naval Postgraduate School. As could be expected, the computer suffered many and varied growing pains in its early life. As a result of this, or of the human manipulation expanding the capability of the program, the effectiveness of LAERO1 was substantially reduced.

Work involving the other three programs would involve simply expanding their capabilities. The trajectory models program, LPATH, presently considers only two guidance laws: line-of-sight guidance and proportional navigation guidance. Other guidance laws which can easily be included in the program include pursuit, beam rider, and combinations of different laws. It might also prove useful to be able to

simulate the entire missile trajectory but still only output the terminal phase of the encounter. Another option would be to provide the target with a controlled trajectory instead of the constant acceleration condition now imposed.

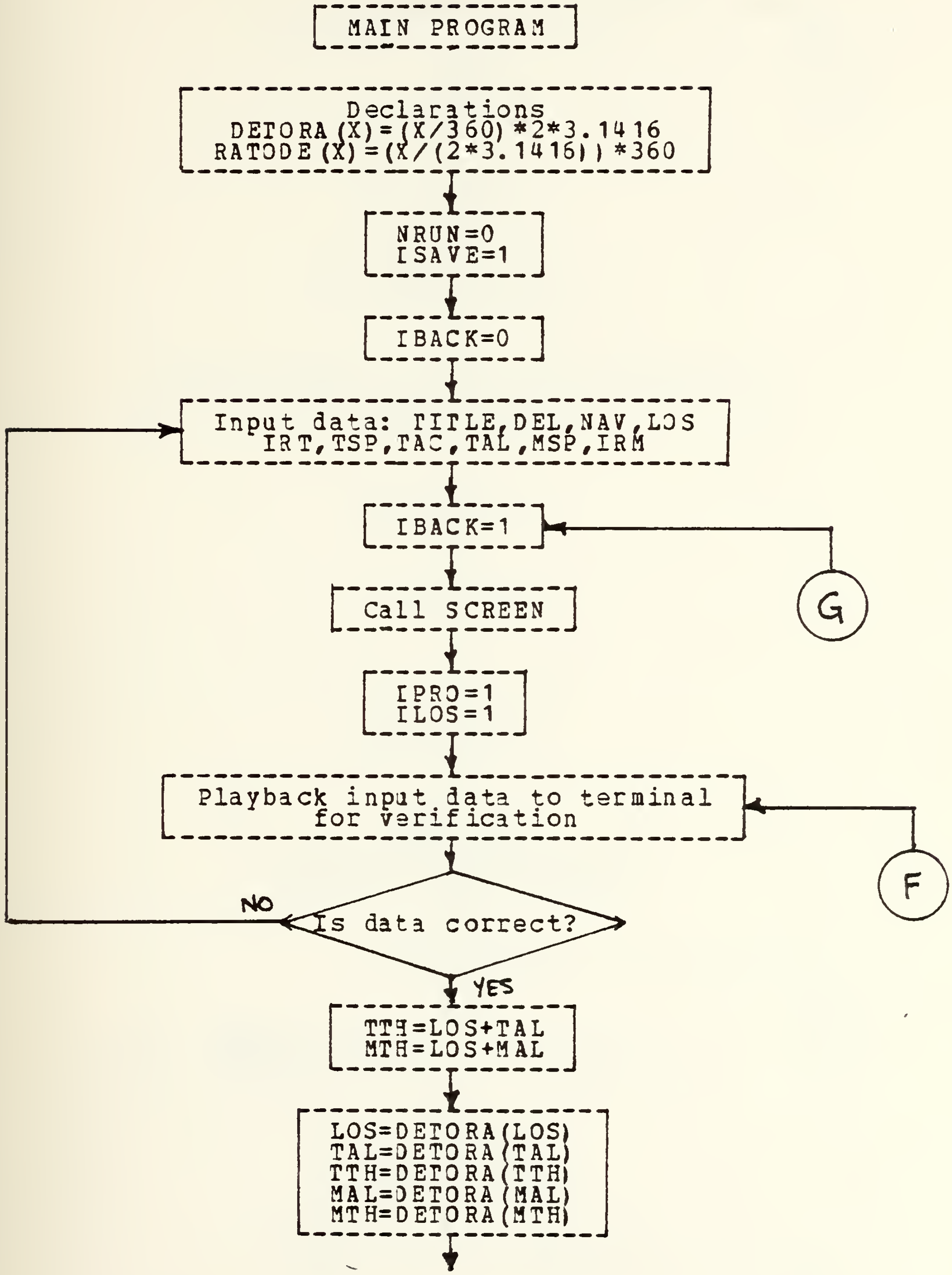
The propulsion sizing program, LPROP, should have the various nozzle options incorporated into the program so that it isn't necessary to manually juggle the program output. Other booster-sustainer grain configurations could be explored, such as the booster grain being cast within the core of the sustainer, or even a motor with only a single grain. Another suggestion for the convenience of the program users is to institute a shopping list of availlable propellants and their characteristics into the program.

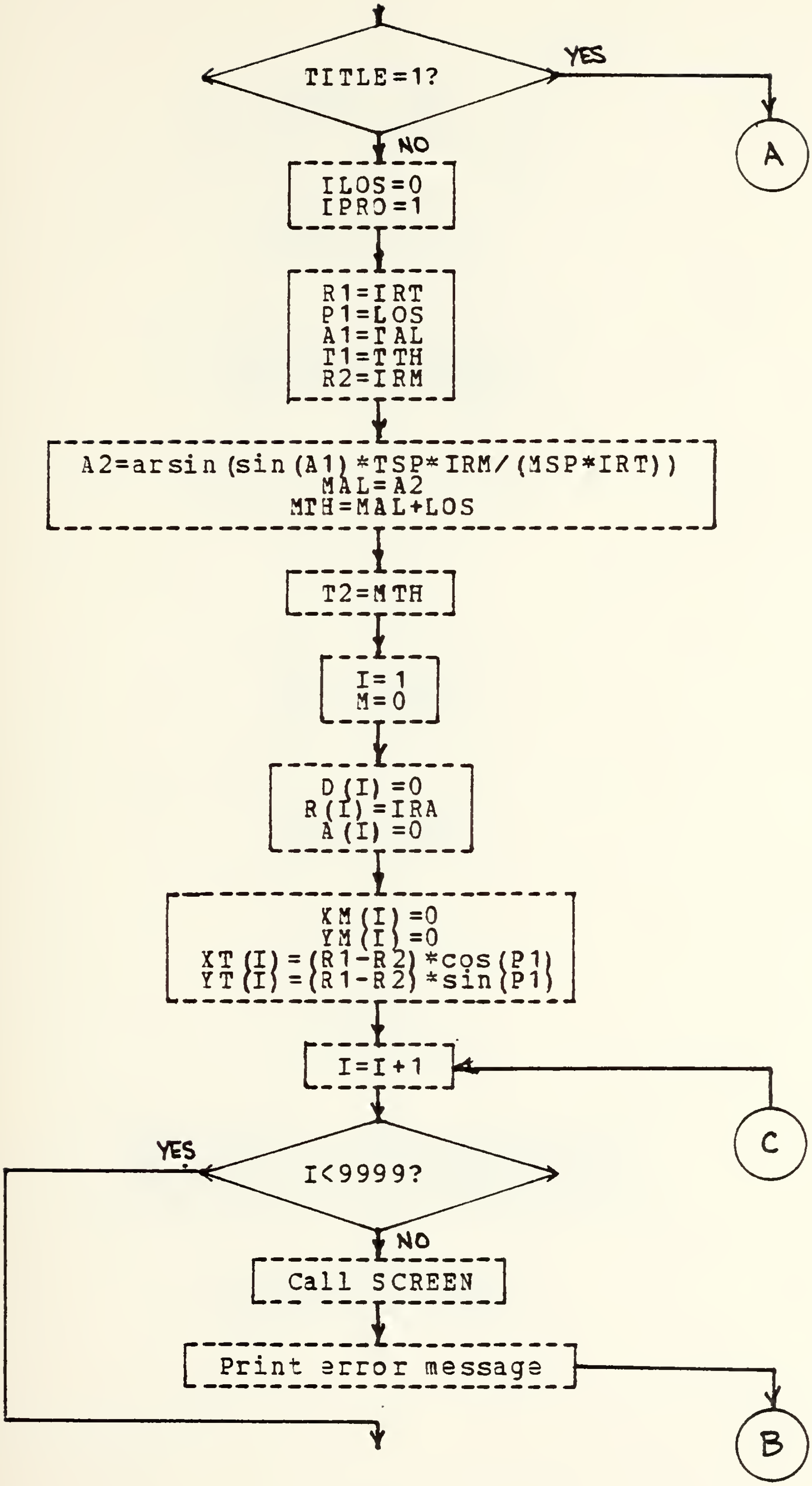
A similar list of available explosives and case materials could be put into the warhead sizing program, LBOMB. These shopping lists would provide ready access to reference information and, at the same time, decrease the number of data values to be manually input into the computer. Since the current program is limited to cylindrical warheads, an area of expansion would be the flexibility of warhead styles, such as curved, shaped charge, continuous rod, etc.

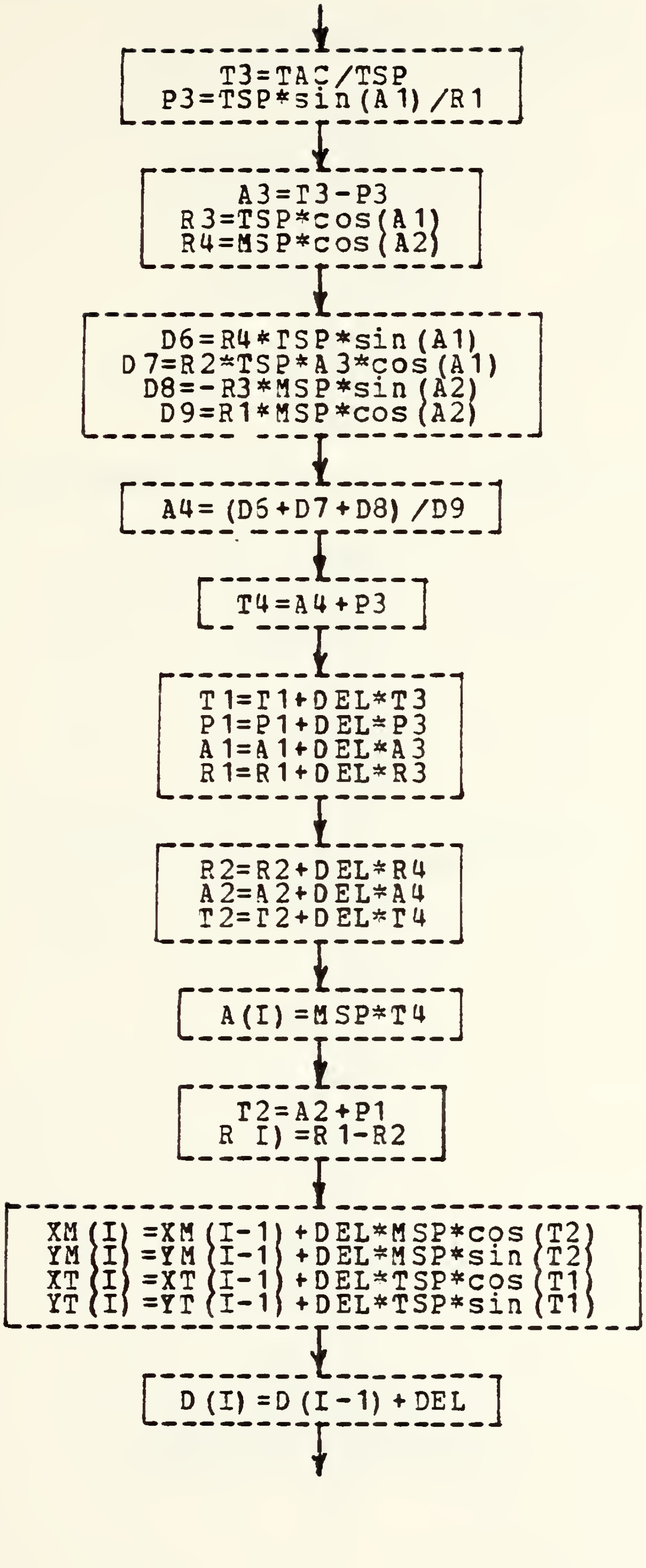
At present, the programs are somewhat hindered by the mechanics involved in producing the printouts and the plots. Due to the results of tailoring a program to be interactive, often it is required to completely exit a program before output can be received. Subsequent design iterations require re-entry into the program, which produces a certain justifyable annoyance to the user. Additionally, the computer center has instituted a new policy of cancelling any jobs with duplicate job names, which can be severely irritating and cumbersome to the persons running the plot routines contained within this thesis. However, the computer center has developed procedures which have the potential to

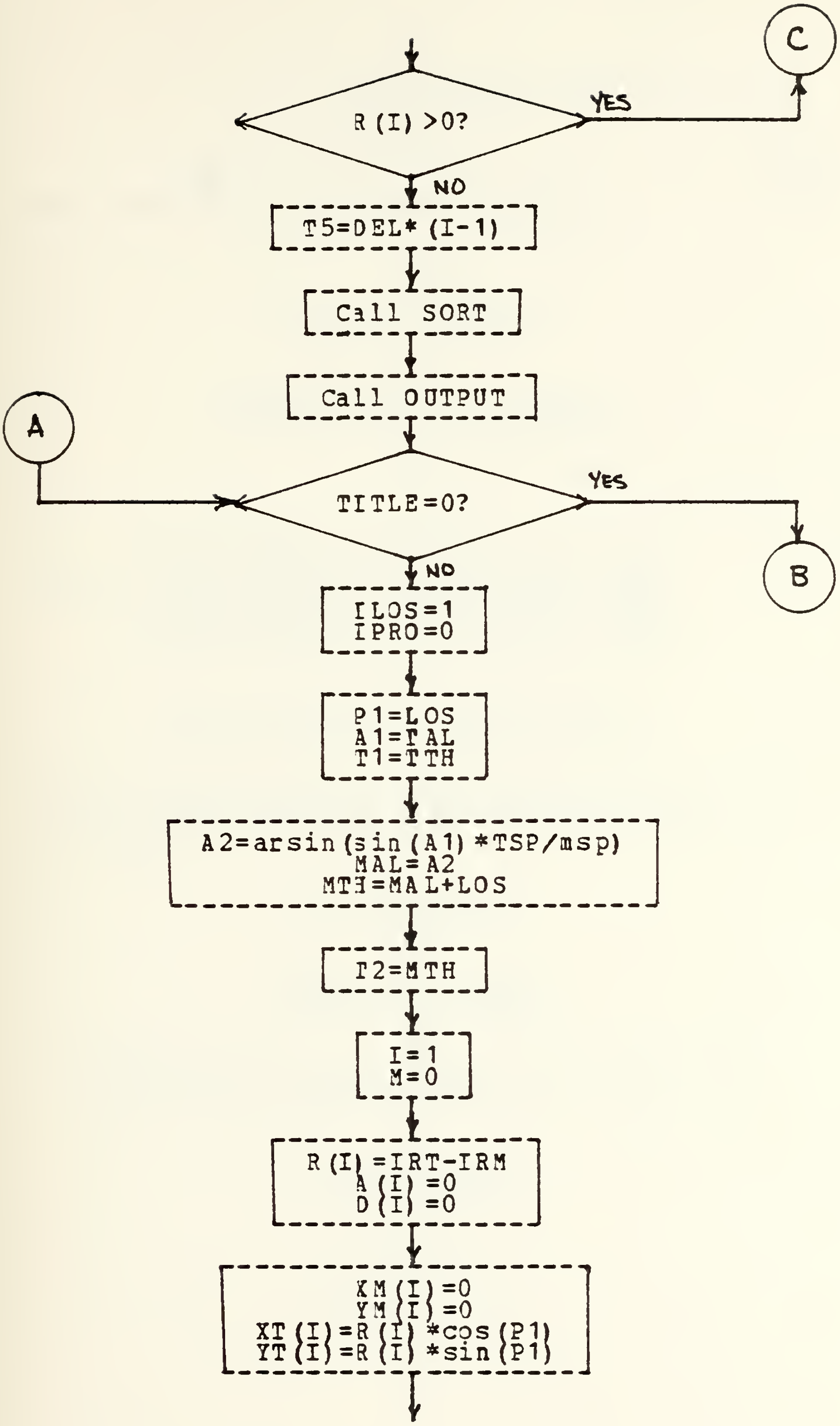
alleviate both of these problems. According to Volume 13, Number 4 of the Computer Center Newsletter, CMS commands can now be invoked from within a FORTRAN program. The print and plot operations presently contained within executive routines can now be placed directly within the source programs. This will remove all current restrictions placed on the numbers of printouts received per session and will label each plot with the user's job name and not the project's job name.

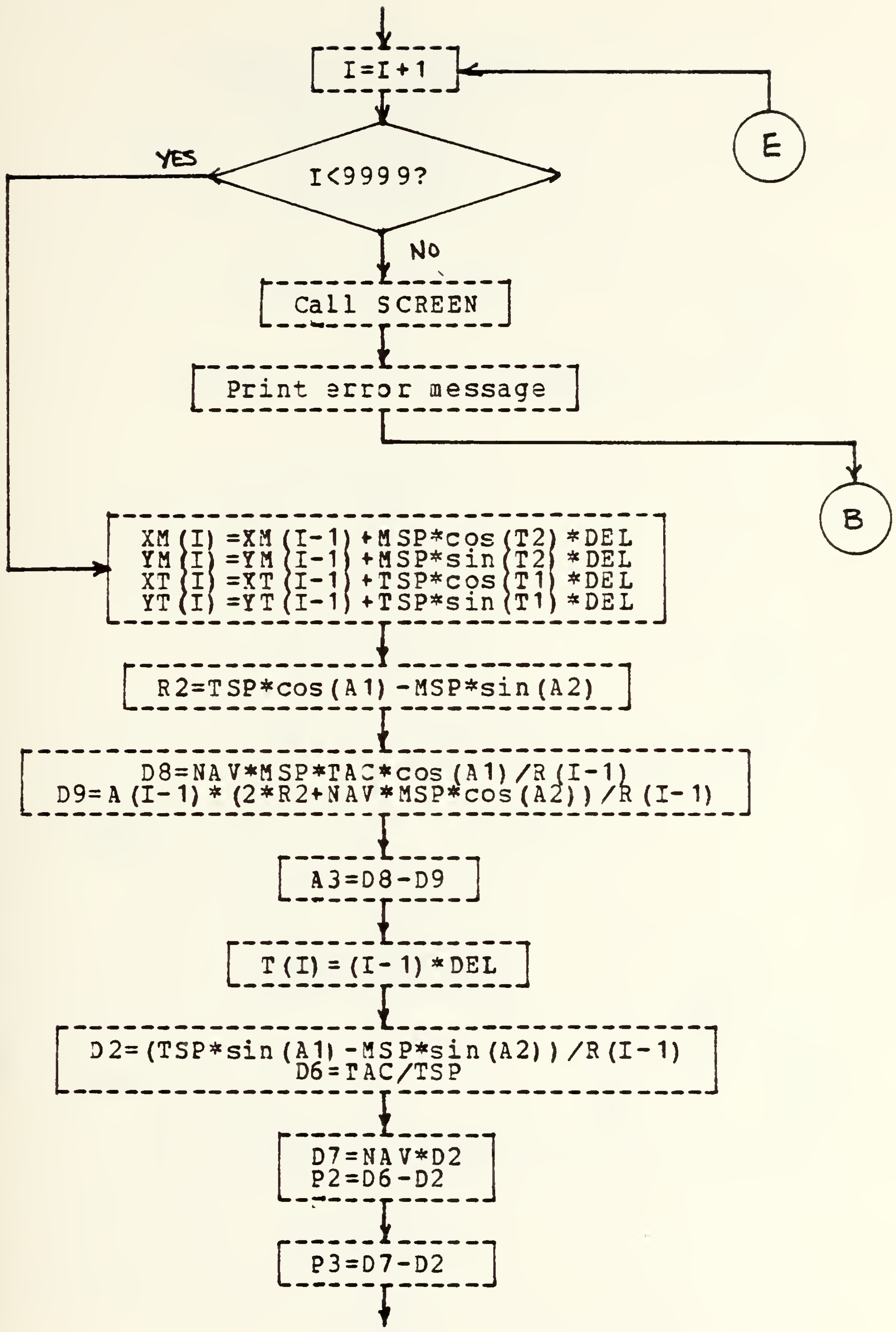
## APPENDIX A. TRAJECTORY MODELS PROGRAM FLOWCHART

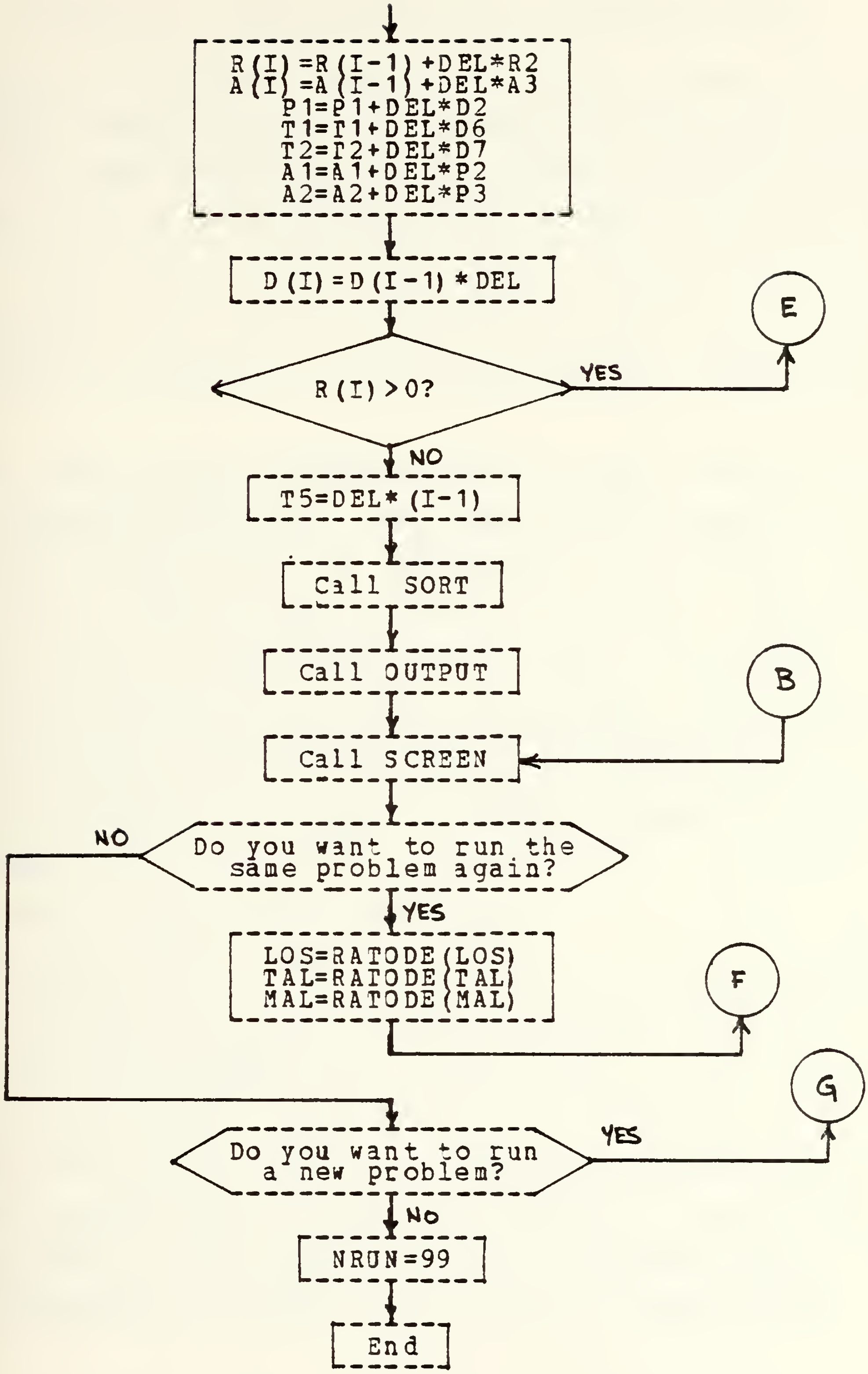



TITLE=1?
YES
A
NO
ILOS=0
IPRO=1
R1=IRT
P1=LOS
A1=TAL
T1=TTH
R2=IRM
A2=arsin(sin(A1)*TSP*IRM/(MSP*IRT))
MAL=A2
MTH=MAL+LOS
T2=MTH
I=1
M=0
D(I)=0
R(I)=IRA
A(I)=0
XM(I)=0
YM(I)=0
XT(I)=(R1-R2)*cos(P1)
YT(I)=(R1-R2)*sin(P1)
I=I+1
C
YES
I<9999?
NO
Call SCREEN
Print error message
B


T3=TAC/TSP
P3=TSP*sin(A1)/R1
A3=T3-P3
R3=TSP*cos(A1)
R4=MSP*cos(A2)
D6=R4*TSP*sin(A1)
D7=R2*TSP*A3*cos(A1)
D8=-R3*MSP*sin(A2)
D9=R1*MSP*cos(A2)
A4=(D6+D7+D8)/D9
T4=A4+P3
T1=T1+DEL*T3
P1=P1+DEL*P3
A1=A1+DEL*A3
R1=R1+DEL*R3
R2=R2+DEL*R4
A2=A2+DEL*A4
T2=T2+DEL*T4
A(I)=MSP*T4
T2=A2+P1
R(I)=R1-R2
XM(I)=XM(I-1)+DEL*MSP*cos(T2)
YM(I)=YM(I-1)+DEL*MSP*sin(T2)
XT(I)=XT(I-1)+DEL*TSP*cos(T1)
YT(I)=YT(I-1)+DEL*TSP*sin(T1)
D(I)=D(I-1)+DEL


C
R(I)>0?
YES
NO
T5=DEL*(I-1)
Call SORT
Call OUTPUT
A
TITLE=0?
YES
B
NO
ILOS=1
IPRO=0
P1=LOS
A1=TAL
T1=TTH
A2=arsin(sin(A1)*TSP/msp)
MAL=A2
MTH=MAL+LOS
T2=MTH
I=1
M=0
R(I)=IRT-IRM
A(I)=0
D(I)=0
XM(I)=0
YM(I)=0
XT(I)=R(I)*cos(P1)
YT(I)=R(I)*sin(P1)


I=I+1
E
YES
I<9999?
NO
Call SCREEN
Print error message
B
XM(I)=XM(I-1)+MSP*cos(T2)*DEL
YM(I)=YM(I-1)+MSP*sin(T2)*DEL
XT(I)=XT(I-1)+TSP*cos(T1)*DEL
YT(I)=YT(I-1)+TSP*sin(T1)*DEL
R2=TSP*cos(A1)-MSP*sin(A2)
D8=NAV*MSP*TAC*cos(A1)/R(I-1)
D9=A(I-1)*(2*R2+NAV*MSP*cos(A2))/R(I-1)
A3=D8-D9
T(I)=(I-1)*DEL
D2=(TSP*sin(A1)-MSP*sin(A2))/R(I-1)
D6=TAC/TSP
D7=NAV*D2
P2=D6-D2
P3=D7-D2


R(I)=R(I-1)+DEL*R2
A(I)=A(I-1)+DEL*A3
P1=P1+DEL*D2
T1=T1+DEL*D6
T2=T2+DEL*D7
A1=A1+DEL*P2
A2=A2+DEL*P3
D(I)=D(I-1)*DEL
E
R(I)>0?
YES
NO
T5=DEL*(I-1)
Call SORT
Call OUTPUT
B
Call SCREEN
NO
Do you want to run the same problem again?
YES
LOS=RATODE(LOS)
TAL=RATODE(TAL)
MAL=RATODE(MAL)
F
G
YES
Do you want to run a new problem?
NO
NRUN=99
End

# APPENDIX B. TRAJECTORY MODELS PROGRAM LISTING

Following the next page is the program listing for the Trajectory Models program. It consists of three main divisions; the executive routines, the FORTRAN IV computational program, and the FORTRAN IV plotting program. The executive routines are used to establish required file definitions, initiate operation of the computational program, supervise the transfer of data to the plotting program, and provide operational information to the program user at appropriate times.

The computational program, LPATH FORTRAN, consists of four subprogram divisions. The MAIN program accepts the input data and performs the calculations for the line of sight and the proportional navigation problems. Subroutine SCREEN is used to prompt the user to clear the terminal screen for proper positioning of the output. Subroutine SORT determines the largest missile acceleration value and the value ranges of the X and Y position coordinates for plotting reference. Finally, subroutine OUTPUT formats the calculated data and provides it to the user, the printer file, and the plot program data file.

The plot program, PATHPLOT FORTRAN, is structured for direct submission to the MVS batch reader from the 3278 terminal. No cards need to be punched or read. Attention must be given to the correct JCL accounting data in the first line of the program; those shown in the listing are for illustrative purposes only. This program receives the data from the computational program and produces a single geographic chart of the encounter in the encounter plane. Multiple problems, up to nine, will overlay on the single chart.

```
FILE: LPATH     EXEC     A   NAVAL POSTGRADUATE SCHOOL

FILEDEF 08 DISK LPATH OUTPUT A0
FILEDEF 07 DISK PATHPLOT DATA A0
&BEGTYPE

YOU WILL HAVE THE OPTION TO OBTAIN BOTH A HARDCOPY PRINTOUT
AND A VERSATEC PLOT OF UP TO NINE ENCOUNTER GEOMETRIES.
THE PLOT IS A SINGLE FRAME WITH ALL NINE GEOMETRIES
SUPERIMPOSED ON ONE ANOTHER.  THE HARDCOPY PRINTOUT IS
IDENTICAL IN FORMAT TO THE TERMINAL OUTPUT.

&END
LOAD LPATH
START
&BEGTYPE

TO OBTAIN A HARDCOPY PRINTOUT OF THE RESULTS, TYPE AND
ENTER:

                    lpathpr

THE OUTPUT WILL BE PRINTED ON THE VM PRINTER IN ROOM 140
AND WILL BE IDENTIFIED BY YOUR USER NUMBER.  IT USUALLY
REQUIRES SEVERAL MINUTES TO OBTAIN THE PRINTOUT.

TO OBTAIN THE PLOT OF YOUR ENCOUNTERS, TYPE AND ENTER:

                    lpathpl

THE PLOT WILL BE PRINTED IN THE COMPUTER ROOM AND WILL BE
PLACED ON TOP OF THE ALPHABETIZED OUTPUT FILE IN ROOM 140.
IT WILL BE IDENTIFIED BY THE JCL JOB NAME "PATHPLOT" AND
USUALLY REQUIRES MANY MINUTES (EVEN HOURS!)  TO BE
OBTAINED.  NOTE....IF MANY USERS ARE REQUESTING PLOTS
SIMULTANEOUSLY, THE COMPUTER CENTER PERSONNEL WILL CANCEL
"EXCESS" JOBS USING THE SAME IDENTIFIER.

&END
```

```
FILE: LPATHPL  EXEC     A   NAVAL POSTGRADUATE SCHOOL

COPY LPATH PLOT A PATHPLOT DATA A PLOT FORTRAN A
EXEC SUBMIT PLOT FORTRAN A
ERASE PLOT FORTRAN A
```

```
FILE: LPATHPR  EXEC     A   NAVAL POSTGRADUATE SCHOOL

PRINT LPATH OUTPUT (LINECOUN 70
```

```
C     27 APRIL 1981
C     THIS PROGRAM COMPARES THE TRAJECTORIES OF TWO GUIDANCE SYSTEM
C     INTERCEPT GEOMETRIES:  LINE OF SIGHT AND PROPORTIONAL
C     NAVIGATION.  THE OUTPUT IS A TABLE OF GEOGRAPHIC POSITIONS, THE
C     MAXIMUM LATERAL ACCELERATION THE INTERCEPTING MISSILE MUST
C     ENDURE, AND THE TIME REQUIRED TO MAKE THE INTERCEPT.
C
C   DECLARATIONS
      REAL DEL,IRT,IRM,LOS,TSP,TAC,TAL,TTH,MSP,MAC,MAL,MTH,NAV
      REAL A1,A2,A3,A4,D2,D6,D7,D8,D9,M,M1,P1,P2,P3,R1,R2,R3
      REAL R4,T1,T2,T3,T4,T5,T2LAST
      INTEGER I,W,TITLE,AGAIN,IBACK,IDO,ISAVE,NRUN,ILOS,IPRO
      DIMENSION XM(9999),YM(9999),XT(9999),YT(9999),A(9999),R(9999)
      DIMENSION T(9999),RP(9999),D(9999),APN(9999),DT2(9999)
      COMMON/BLOCK1/A,XM,YM,XT,YT,M,XPOS,XNEG,YPOS,YNEG,I
      COMMON/BLOCK2/DEL,NAV,LOS,IRT,IRM,TSP,TAC,TAL,MSP,MAC,MAL,D,R,T5,
     *ISAVE,NRUN,ILOS,IPRO
      DETORA(X)=(X/360)*2*3.1415926535
      RATODE(X)=(X/(2*3.1415926535))*360
      NRUN=0
      ISAVE=1
    1 IBACK=0
C
C   INPUT PROBLEM PARAMETERS
      WRITE (6,12)
   12 FORMAT (/1X,T13,'INPUT PROBLEM PARAMETERS')
      WRITE (6,14)
   14 FORMAT (1X,T2,'FOR LINE OF SIGHT GUIDANCE INTERCEPT TRAJECTORY, IN
     +PUT "0";'/,T2,'FOR PROPORTIONAL NAVIGATION GUIDANCE INTERCEPT TRAJ
     +ECTORY, INPUT "1";'/,T2,'FOR BOTH INTERCEPT TRAJECTORIES, INPUT "2
     +".  (INTEGER)')
      READ (6,16)TITLE
   16 FORMAT (1I1)
10001 WRITE (6,15)
   15 FORMAT (1X,T2,'INPUT INTEGRATION TIME INCREMENT (SECONDS, DECIMAL)
     *:')
      READ (6,117)DEL
  117 FORMAT (F10.5)
   17 FORMAT (F10.3)
      IF (IBACK.EQ.1) GO TO 204
10002 WRITE (6,18)
   18 FORMAT (1X,T2,'INPUT NAVIGATION CONSTANT FOR PROPORTIONAL NAVIGATI
     *ON (DECIMAL):')
      READ (6,17)NAV
      IF (IBACK.EQ.1) GO TO 204
10003 WRITE (6,19)
   19 FORMAT (1X,T2,'INPUT LINE-OF-SIGHT ANGLE (DEGREES, DECIMAL):')
      READ (6,17)LOS
```

```
      IF (IBACK.EQ.1) GO TO 204                                         LPA00520
10004 WRITE (6,20)                                                      LPA00530
   20 FORMAT (1X,T2,'INPUT TARGET RANGE FROM MISSILE LAUNCH SITE (METERSLPA00540
     *, DECIMAL):')                                                     LPA00550
      READ (6,17)IRT                                                    LPA00560
      IF (IBACK.EQ.1) GO TO 204                                         LPA00570
10005 WRITE (6,21)                                                      LPA00580
   21 FORMAT (1X,T2,'INPUT TARGET SPEED (METERS/SECOND, DECIMAL):')     LPA00590
      READ (6,17)TSP                                                    LPA00600
      IF (IBACK.EQ.1) GO TO 204                                         LPA00610
10006 WRITE (6,22)                                                      LPA00620
   22 FORMAT (1X,T2,'INPUT TARGET LATERAL ACCELERATION (M/SEC/SEC, DECIMLPA00630
     *AL):')                                                            LPA00640
      READ (6,17)TAC                                                    LPA00650
      IF (IBACK.EQ.1) GO TO 204                                         LPA00660
10007 WRITE (6,23)                                                      LPA00670
   23 FORMAT (1X,T2,'INPUT TARGET ALPHA (DEGREES, DECIMAL):')           LPA00680
      READ (6,17)TAL                                                    LPA00690
      IF (IBACK.EQ.1) GO TO 204                                         LPA00700
10008 WRITE (6,25)                                                      LPA00710
   25 FORMAT (1X,T2,'INPUT MISSILE SPEED (METERS/SECOND, DECIMAL):')    LPA00720
      READ (6,17)MSP                                                    LPA00730
      IF (IBACK.EQ.1) GO TO 204                                         LPA00740
10009 WRITE (6,26)                                                      LPA00750
   26 FORMAT (1X,T2,'INPUT MISSILE RANGE FROM LAUNCH SITE (METERS, DECIMLPA00760
     *AL):')                                                            LPA00770
      READ (6,17)IRM                                                    LPA00780
C                                                                       LPA00790
C  COVER PAGE PRINTOUT                                                  LPA00800
      IBACK=1                                                           LPA00810
  204 CALL SCREEN                                                       LPA00820
      IPRO=1                                                            LPA00830
      ILOS=1                                                            LPA00840
      WRITE (6,33)                                                      LPA00850
   33 FORMAT (/1X,T28,'PROBLEM PARAMETERS')                             LPA00860
      WRITE (6,132)DEL,NAV,LOS,IRT,TSP,TAC,TAL,MSP,IRM                  LPA00870
  132 FORMAT (1X,T16,'01) TIME INCREMENT',T40,F10.4,' SECONDS'/,        LPA00880
     +T16,'02) NAVIGATION CONSTANT',T39,F10.3/,                         LPA00890
     +T16,'03) LINE-OF-SIGHT ANGLE',T39,F10.3,' DEGREES'/,              LPA00900
     +T16,'04) TARGET RANGE',T39,F10.3,' METERS'/,                      LPA00910
     +T16,'05) TARGET SPEED',T39,F10.3,' METERS/SEC'/,                  LPA00920
     +T16,'06) TARGET ACCELERATION',T39,F10.3,' M/SEC/SEC'/,            LPA00930
     +T16,'07) TARGET ALPHA',T39,F10.3,' DEGREES'/,                     LPA00940
     +T16,'08) MISSILE SPEED',T39,F10.3,' METERS/SEC'/,                 LPA00950
     +T16,'09) MISSILE RANGE',T39,F10.3,' METERS')                      LPA00960
      WRITE (6,150)                                                     LPA00970
  150 FORMAT (1X/,T15,'IS THIS DATA SUMMARY CORRECT? (00=YES,  IF NO,'/, LPA00980
     *T15,'ENTER THE TWO DIGIT NUMBER OF THE INCORRECT ITEM.'/,         LPA00990
```

```
     *T15,'(TWO-DIGIT INTEGER)')                                             LPA01000
      READ (6,161)AGAIN                                                      LPA01010
  161 FORMAT (1I2)                                                           LPA01020
      IF (AGAIN.EQ.00) GO TO 205                                             LPA01030
      GO TO (10001,10002,10003,10004,10005,10006,10007,10008,10009),         LPA01040
     *AGAIN                                                                  LPA01050
C                                                                            LPA01060
C                                                                            LPA01070
 205  TTH=LOS+TAL                                                            LPA01080
      MTH=LOS+MAL                                                            LPA01090
      LOS=DETORA(LOS)                                                        LPA01100
      TAL=DETORA(TAL)                                                        LPA01110
      TTH=DETORA(TTH)                                                        LPA01120
      MAL=DETORA(MAL)                                                        LPA01130
      MTH=DETORA(MTH)                                                        LPA01140
C                                                                            LPA01150
C                                                                            LPA01160
      IF (TITLE.EQ.1) GO TO 299                                              LPA01170
C                                                                            LPA01180
C   LINE OF SIGHT GUIDANCE INTERCEPT TRAJECTORY CALCULATIONS                 LPA01190
      ILOS=0                                                                 LPA01200
      IPRO=1                                                                 LPA01210
C                                                                            LPA01220
C   PROGRAM                                                                  LPA01230
      R1=IRT                                                                 LPA01240
      P1=LOS                                                                 LPA01250
      A1=TAL                                                                 LPA01260
      T1=TTH                                                                 LPA01270
      R2=IRM                                                                 LPA01280
      A2=ARSIN(SIN(A1)*TSP*IRM/(MSP*IRT))                                    LPA01290
      MAL=A2                                                                 LPA01300
      MTH=LOS+MAL                                                            LPA01310
      T2=MTH                                                                 LPA01320
      I=1                                                                    LPA01330
      M=0                                                                    LPA01340
      D(I)=0                                                                 LPA01350
      R(I)=IRA                                                               LPA01360
      A(I)=0                                                                 LPA01370
      XM(I)=0                                                                LPA01380
      YM(I)=0                                                                LPA01390
      XT(I)=(R1-R2)*COS(P1)                                                  LPA01400
      YT(I)=(R1-R2)*SIN(P1)                                                  LPA01410
  210 I=I+1                                                                  LPA01420
      IF (I.LT.9999) GO TO 211                                               LPA01430
      CALL SCREEN                                                            LPA01440
      WRITE (6,212)                                                          LPA01450
  212 FORMAT (1X,'YOU HAVE SUCCESSFULLY EXCEEDED THE CAPABILITY OF THIS LPA01460
     *PROGRAM'/,1X,'BY REQUIRING MORE THAN 9999 ITERATIONS TO COMPLETE  LPA01470
```

```
     *THE SOLUTION.'/,1X,'IF YOU STRONGLY DESIRE A SOLUTION FOR THIS ENCLPA01480
     *OUNTER, INCREASE'/,1X,'THE SIZE OF YOUR TIME INCREMENT AND RERUN. LPA01490
     * IT IS ALSO STRONGLY RECOMMENDED'/,1X,'THAT YOU REVIEW THE GEOMETRLPA01500
     *Y OF THE ENCOUNTER TO ENSURE IT IS POSSIBLE'/,1X,'FOR THE ENCOUNTELPA01510
     *R TO OCCUR.')                                                     LPA01520
      GO TO 999                                                         LPA01530
 211  T3=TAC/TSP                                                        LPA01540
      P3=TSP*SIN(A1)/R1                                                 LPA01550
      A3=T3-P3                                                          LPA01560
      R3=TSP*COS(A1)                                                    LPA01570
      R4=MSP*COS(A2)                                                    LPA01580
      D6=R4*TSP*SIN(A1)                                                 LPA01590
      D7=R2*TSP*A3*COS(A1)                                              LPA01600
      D8=-R3*MSP*SIN(A2)                                                LPA01610
      D9=R1*MSP*COS(A2)                                                 LPA01620
      A4=(D6+D7+D8)/D9                                                  LPA01630
      T4=A4+P3                                                          LPA01640
      T1=T1+DEL*T3                                                      LPA01650
      P1=P1+DEL*P3                                                      LPA01660
      A1=A1+DEL*A3                                                      LPA01670
      R1=R1+DEL*R3                                                      LPA01680
      R2=R2+DEL*R4                                                      LPA01690
      A2=A2+DEL*A4                                                      LPA01700
      T2=T2+DEL*T4                                                      LPA01710
      A(I)=MSP*T4                                                       LPA01720
 220  T2=A2+P1                                                          LPA01730
      R(I)=R1-R2                                                        LPA01740
      XM(I)=XM(I-1)+DEL*MSP*COS(T2)                                     LPA01750
      YM(I)=YM(I-1)+DEL*MSP*SIN(T2)                                     LPA01760
      XT(I)=XT(I-1)+DEL*TSP*COS(T1)                                     LPA01770
      YT(I)=YT(I-1)+DEL*TSP*SIN(T1)                                     LPA01780
      D(I)=D(I-1)+DEL                                                   LPA01790
      IF (R(I).GT.0) GO TO 210                                          LPA01800
      T5=DEL*(I-1)                                                      LPA01810
      CALL SORT                                                         LPA01820
      CALL OUTPUT                                                       LPA01830
C                                                                       LPA01840
C                                                                       LPA01850
C                                                                       LPA01860
 299  IF (TITLE.EQ.0) GO TJ 999                                         LPA01870
C                                                                       LPA01880
C PROPORTIONAL NAVIGATION GUIDANCE INTERCEPT TRAJECTORY CALCULATIONS    LPA01890
      ILOS=1                                                            LPA01900
      IPRO=0                                                            LPA01910
C                                                                       LPA01920
C PROGRAM                                                               LPA01930
      P1=LOS                                                            LPA01940
      A1=TAL                                                            LPA01950
```

```
      T1=TTH                                                            LPA01960
      A2=ARSIN(SIN(A1)*TSP/MSP)                                         LPA01970
      MAL=A2                                                            LPA01980
      MTH=MAL+LOS                                                       LPA01990
      T2=MTH                                                            LPA02000
      I=1                                                               LPA02010
      M=0                                                               LPA02020
      R(I)=IRT-IRM                                                      LPA02030
      A(I)=MAC                                                          LPA02040
      D(I)=0                                                            LPA02050
      XM(I)=0                                                           LPA02060
      YM(I)=0                                                           LPA02070
      XT(I)=R(I)*COS(P1)                                                LPA02080
      YT(I)=R(I)*SIN(P1)                                                LPA02090
  310 I=I+1                                                             LPA02100
      IF (I.LT.9999) GO TO 311                                          LPA02110
      CALL SCREEN                                                       LPA02120
      WRITE (6,212)                                                     LPA02130
      GO TO 999                                                         LPA02140
  311 XM(I)=XM(I-1)+MSP*COS(T2)*DEL                                     LPA02150
      YM(I)=YM(I-1)+MSP*SIN(T2)*DEL                                     LPA02160
      XT(I)=XT(I-1)+TSP*COS(T1)*DEL                                     LPA02170
      YT(I)=YT(I-1)+TSP*SIN(T1)*DEL                                     LPA02180
      R2=TSP*COS(A1)-MSP*COS(A2)                                        LPA02190
      D8=NAV*MSP*TAC*COS(A1)/R(I-1)                                     LPA02200
      D9=A(I-1)*(2*R2+NAV*MSP*COS(A2))/R(I-1)                           LPA02210
      A3=D8-D9                                                          LPA02220
      T(I)=(I-1)*DEL                                                    LPA02230
      D2=(TSP*SIN(A1)-MSP*SIN(A2))/R(I-1)                               LPA02240
      D6=TAC/TSP                                                        LPA02250
      D7=NAV*D2                                                         LPA02260
      P2=D6-D2                                                          LPA02270
      P3=D7-D2                                                          LPA02280
      R(I)=R(I-1)+DEL*R2                                                LPA02290
      A(I)=A(I-1)+DEL*A3                                                LPA02300
      P1=P1+DEL*D2                                                      LPA02310
      T1=T1+DEL*D6                                                      LPA02320
      T2=T2+DEL*D7                                                      LPA02330
      A1=A1+DEL*P2                                                      LPA02340
      A2=A2+DEL*P3                                                      LPA02350
  320 D(I)=D(I-1)+DEL                                                   LPA02360
      IF (R(I).GT.0) GO TO 310                                          LPA02370
  330 T5=DEL*(I-1)                                                      LPA02380
      CALL SORT                                                         LPA02390
      CALL OUTPUT                                                       LPA02400
C                                                                       LPA02410
C                                                                       LPA02420
  999 CALL SCREEN                                                       LPA02430
```

```
  998 WRITE (6,410)
  410 FORMAT (/1X,'DO YOU WANT TO RUN THIS PROBLEM AGAIN? 0=YES, 1=NO')
      READ (6,16) IDO
      IF (IDO.EQ.1) GO TO 420
      LOS=RATODE(LOS)
      TAL=RATODE(TAL)
      MAL=RATODE(MAL)
      GO TO 204
  420 WRITE (6,430)
  430 FORMAT (1X,'DO YOU WANT TO RUN A NEW PROBLEM? 0=YES, 1=NO')
      READ (6,16) IDO
      IF (IDO.EQ.0) GO TO 1
      NRUN=99
      WRITE (7,144) NRUN,I
      WRITE (7,145)
  145 FORMAT ('/*')
  144 FORMAT (I2,I4)
      STOP
      END
C
C
      SUBROUTINE SCREEN
      WRITE (6,600)
  600 FORMAT (1X,'CLEAR SCREEN AND ENTER "0"')
      READ (6,16) ISCR
   16 FORMAT (1I1)
      RETURN
      END
C
C
      SUBROUTINE SORT
      DIMENSION A(9999),XM(9999),YM(9999),XT(9999),YT(9999)
      REAL A,M,XM,YM,XT,YT,XPOS,XNEG,YPOS,YNEG
      INTEGER I,W,Z
      COMMON/BLOCK1/A,XM,YM,XT,YT,M,XPOS,XNEG,YPOS,YNEG,I
      XPOS=0.0
      XNEG=0.0
      YPOS=0.0
      YNEG=0.0
      Z=I-1
      DO 10 W=1,Z
         IF (ABS(A(W)).GT.ABS(M)) M=A(W)
         IF (XT(W).GT.XPOS) XPOS=XT(W)
         IF (XM(W).GT.XPOS) XPOS=XM(W)
         IF (XT(W).LT.XNEG) XNEG=XT(W)
         IF (XM(W).LT.XNEG) XNEG=XM(W)
         IF (YT(W).GT.YPOS) YPOS=YT(W)
         IF (YM(W).GT.YPOS) YPOS=YM(W)
```

```
         IF (YT(W).LT.YNEG) YNEG=YT(W)
         IF (YM(W).LT.YNEG) YNEG=YM(W)
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE OUTPUT
      REAL D,XM,YM,XT,YT,R,A,M,T5,M1,LOS1,TAL1,MAL1,E,F,G
      REAL DEL,NAV,LOS,IRT,IRM,TSP,TAC,TAL,MSP,MAC,MAL
      INTEGER ISAVE,W,I,NRUN,ILOS,IPRO,II
      DIMENSION D(9999),XM(9999),YM(9999),XT(9999),YT(9999)
      DIMENSION R(9999),A(9999)
      COMMON/BLOCK1/A,XM,YM,XT,YT,M,XPOS,XNEG,YPOS,YNEG,I
      COMMON/BLOCK2/DEL,NAV,LOS,IRT,IRM,TSP,TAC,TAL,MSP,MAC,MAL,D,R,T5,
     *ISAVE,NRUN,ILOS,IPRO
      RATODE(X)=(X/(2*3.141592653 5))*360
C
      M1=M/9.80665
      IF (ISAVE.EQ.0) GO TO 250
C
C
      CALL SCREEN
      IF (ILOS.EQ.0) WRITE (6,133)
      IF (IPRO.EQ.0) WRITE (6,134)
      WRITE (6,170)
      DO 240 W=1,I,25
         WRITE (6,107) D(W),XM(W),YM(W),XT(W),YT(W),R(W),A(W)
  240 CONTINUE
      WRITE (6,107) D(I-1),XM(I-1),YM(I-1),XT(I-1),YT(I-1),
     *R(I-1),A(I-1)
  107 FORMAT (1X,F6.3,5(2X,F8.1),2X,F10.3)
      WRITE (6,135) M,M1,T5
  135 FORMAT (T15,'MAXIMUM LATERAL ACCELERATION ON THE MISSILE'/,
     *T15,'IS ',F10.3,' M/SEC/SEC, OR ',F9.2,' G"S.'/,
     *T15,'THE TIME TO INTERCEPT IS ',F6.3,' SECONDS.')
      WRITE (6,143)
  143 FORMAT (/1X,'DO YOU WISH TO INCLUDE THIS OUTPUT IN THE PRINTOUT AN
     *D THE PLOT?'/,1X,'(REMEMBER THAT ALL PLOTS FROM A SINGLE SESSION W
     *ILL OVERLAY EACH OTHER.)'/,1X,'0=YES, 1=NO')
      READ (6,16) ISAVE
   16 FORMAT (I1)
      IF (ISAVE.EQ.1) GO TO 270
C
  250 NRUN=NRUN+1
      IF (NRUN.LT.10) GO TO 255
      WRITE (6,253)
  253 FORMAT (1X,'YOU HAVE REQUESTED MORE THAN 9 ENCOUNTER SITUATIONS BE
```

```
     * SAVED AND PLOTTED'/,1X,'WHICH, UNFORTUNATELY, IS NOT POSSIBLE.  I
     *F YOU WANT ADDITIONAL PLOTS, EXIT THE'/,1X,'PROGRAM, OUTPUT THE LA
     *ST 9 SITUATIONS AND RE-ENTER THE PROGRAM BY TYPING'/,1X,'"LPATH" A
     *ND ENTERING.')
      GO TO 270
  255 WRITE (8,32) NRUN
   32 FORMAT (//1X,'$$$$ RUN NUMBER ',I2)
      WRITE (8,33)
   33 FORMAT (T25,'PROBLEM PARAMETERS')
      DR=IRT-IRM
      TAL1=RATODE(TAL)
      MAL1=RATODE(MAL)
      LOS1=RATODE(LOS)
      WRITE (8,34) DEL,NAV,LOS1,DR,TSP,TAC,TAL1,MSP,MAL1
   34 FORMAT (1X,T13,'01) TIME INCREMENT',T40,F10.4,' SECONDS'/,
     +T13,'02) NAVIGATION CONSTANT',T39,F10.3/,
     +T13,'03) LINE-OF-SIGHT ANGLE',T39,F10.3,' DEGREES'/,
     +T13,'04) INITIAL SEPARATION',T39,F10.3,' METERS'/,
     +T13,'05) TARGET SPEED',T39,F10.3,' METERS/SEC'/,
     +T13,'06) TARGET ACCELERATION',T39,F10.3,' M/SEC/SEC'/,
     +T13,'07) TARGET ALPHA',T39,F10.3,' DEGREES'/,
     +T13,'08) MISSILE SPEED',T39,F10.3,' METERS/SEC'/,
     +T13,'09) MISSILE INITIAL ALPHA',T39,F10.3,' DEGREES')
      IF (ILOS.EQ.0) WRITE (8,133)
  133 FORMAT (/T12,'LINE OF SIGHT GUIDANCE INTERCEPT TRAJECTORY')
      IF (IPRO.EQ.0) WRITE (8,134)
  134 FORMAT (/T07,'PROPORTIONAL NAVIGATION GUIDANCE INTERCEPT TRAJECTOR
     *Y')
      WRITE (8,170)
  170 FORMAT (1X,'PROBLEM',T13,'--POSITION COORDINATES (METERS)--',
     *T52,'RANGE',T62,'ACCEL.'/,1X,'TIME(S)',T15,'XM',T25,'YM',T35,
     *'XT',T45,'YT',T51,'(METERS)',T61,'(M/S/S)')
      II=(I/25)+2
      E=25.
      F=I
      DO 5 J=1,50
         G=F-E
         IF (G.EQ.0.) GO TO 10
         E=E+25.
    5 CONTINUE
      GO TO 20
   10 II=II-1
   20 CONTINUE
      WRITE (7,140) NRUN,II
  140 FORMAT (I2,I4)
      DO 260 W=1,I,25
         WRITE (8,107) D(W),XM(W),YM(W),XT(W),YT(W),R(W),A(W)
         WRITE (7,141) XM(W),YM(W),XT(W),YT(W)
```

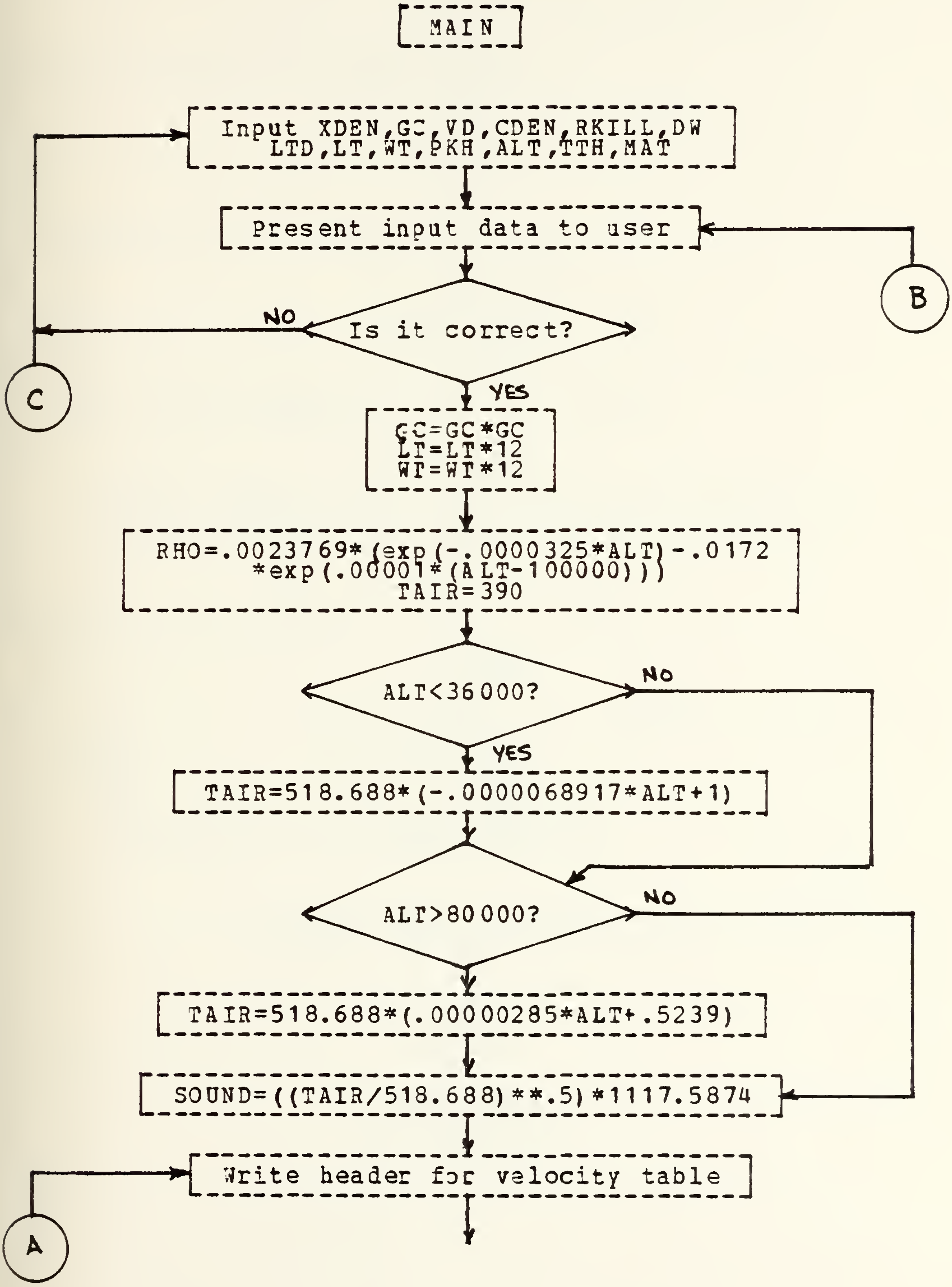
```
260 CONTINUE                                                                  LPA03880
    WRITE (8,107) D(I-1),XM(I-1),YM(I-1),XT(I-1),YT(I-1),R(I-1),A(I-1)LPA03890
    WRITE (7,141) XM(I),YM(I),XT(I),YT(I)                                     LPA03900
141 FORMAT (4(F10.3))                                                         LPA03910
    WRITE (8,135) M,M1,T5                                                     LPA03920
    WRITE (7,141) XPOS,XNEG,YPOS,YNEG                                         LPA03930
    ISAVE=1                                                                   LPA03940
270 CONTINUE                                                                  LPA03950
    RETURN                                                                    LPA03960
    END                                                                       LPA03970
```

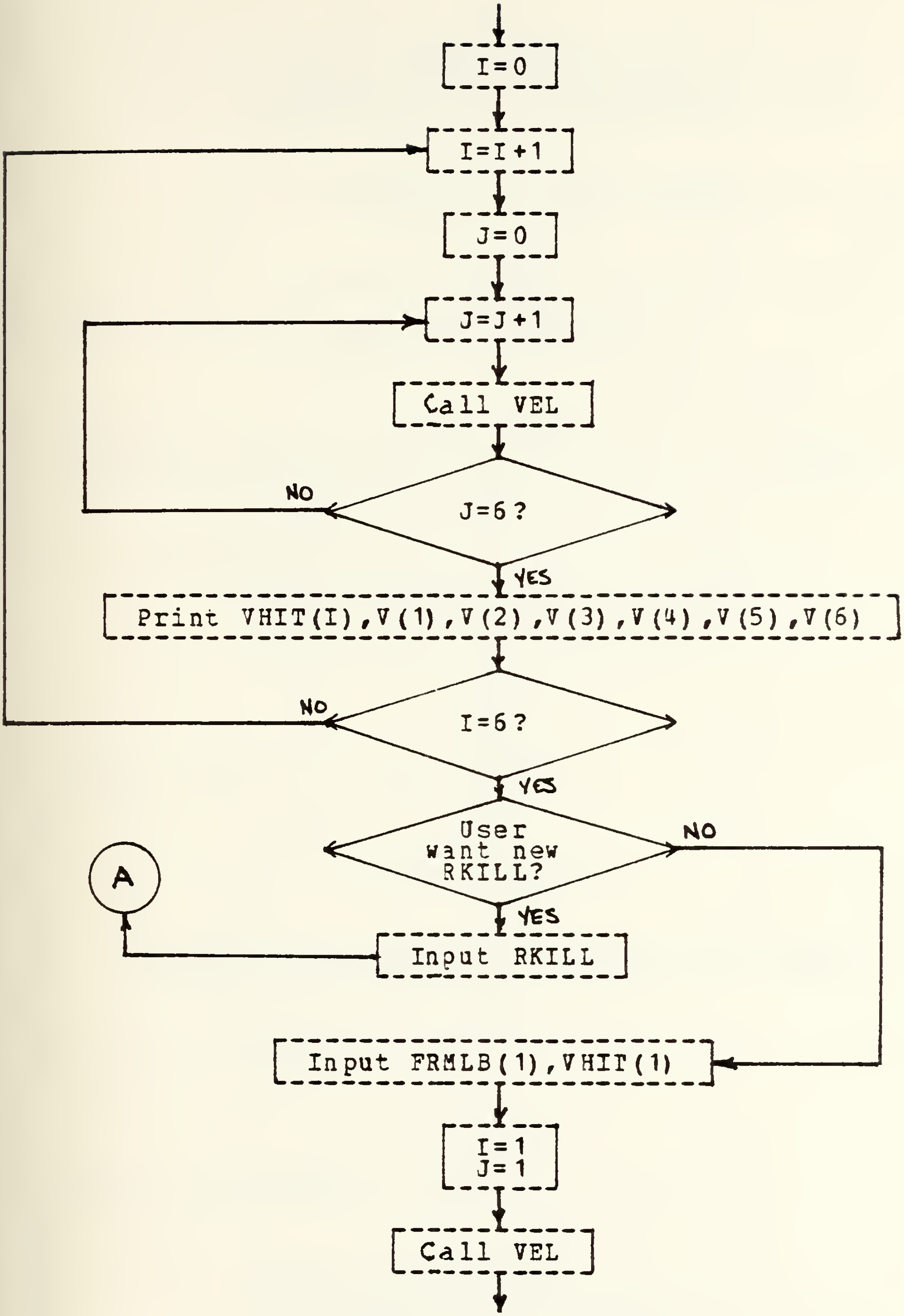
```
//PATHPLOT JOB (1414,0483),'LINDSEY',CLASS=B                                LPA00040
// EXEC FRTXCLGP                                                            LPA00050
//FORT.SYSIN DD *                                                           LPA00060
C     LPATH PLOTTING ROUTINE(MAXIMUM OF 9 SIMULTANEOUS PLOTS)               LPA00070
C     READ IN DATA                                                          LPA00080
C                                                                           LPA00090
      REAL XM,YM,XT,YT,XPOS,XNEG,YPOS,YNEG,X,Y,XMAX,XMIN,YMAX,YMIN          LPA00100
      REAL XMININ,YMININ,XSPAN,YSPAN,SCALES,XO,YO,SYMB                      LPA00110
      INTEGER K,J,N,I,Z                                                     LPA00120
      DIMENSION XM(500,9),YM(500,9),XT(500,9),YT(500,9)                     LPA00130
      DIMENSION X(500),Y(500),SYMB(9)                                       LPA00140
      DIMENSION I(9)                                                        LPA00150
      DATA SYMB/1.,2.,3.,4.,5.,6.,7.,8.,9./                                 LPA00160
      XMAX=0.0                                                              LPA00170
      XMIN=0.0                                                              LPA00180
      YMAX=0.0                                                              LPA00190
      YMIN=0.0                                                              LPA00200
  100 READ (5,105) NRUN,I(NRUN)                                             LPA00210
  105 FORMAT (I2,I4)                                                        LPA00220
      IF (NRUN.EQ.99) GO TO 120                                             LPA00230
      N=NRUN                                                                LPA00240
      DO 110 K=1,500                                                        LPA00250
         READ (5,115) XM(K,N),YM(K,N),XT(K,N),YT(K,N)                       LPA00260
         IF (K.EQ.I(N)) GO TO 117                                           LPA00270
  110 CONTINUE                                                              LPA00280
  115 FORMAT (4(F10.3))                                                     LPA00290
  117 READ (5,115) XPOS,XNEG,YPOS,YNEG                                      LPA00300
      IF (XPOS.GT.XMAX) XMAX=XPOS                                           LPA00310
      IF (XNEG.LT.XMIN) XMIN=XNEG                                           LPA00320
      IF (YPOS.GT.YMAX) YMAX=YPOS                                           LPA00330
      IF (YNEG.LT.YMIN) YMIN=YNEG                                           LPA00340
      GO TO 100                                                             LPA00350
  120 CONTINUE                                                              LPA00360
C                                                                           LPA00370
C     INITIALIZE PLOTTING                                                   LPA00380
      CALL PLOTS(0,0,0)                                                     LPA00390
C                                                                           LPA00400
C     ESTABLISH PLOT "WINDOW"                                               LPA00410
      XSPAN=XMAX-XMIN                                                       LPA00420
      YSPAN=YMAX-YMIN                                                       LPA00430
      IF ((YSPAN/7.0).GT.(XSPAN/9.0)) GO TO 130                             LPA00440
      SCALES=XSPAN/9.0                                                      LPA00450
      YMININ=YMIN/SCALES                                                    LPA00460
      YMAX=(7.0+YMININ)*SCALES                                              LPA00470
      YSPAN=YMAX-YMIN                                                       LPA00480
      GO TO 135                                                             LPA00490
  130 SCALES=YSPAN/7.0                                                      LPA00500
      XMININ=XMIN/SCALES                                                    LPA00510
```

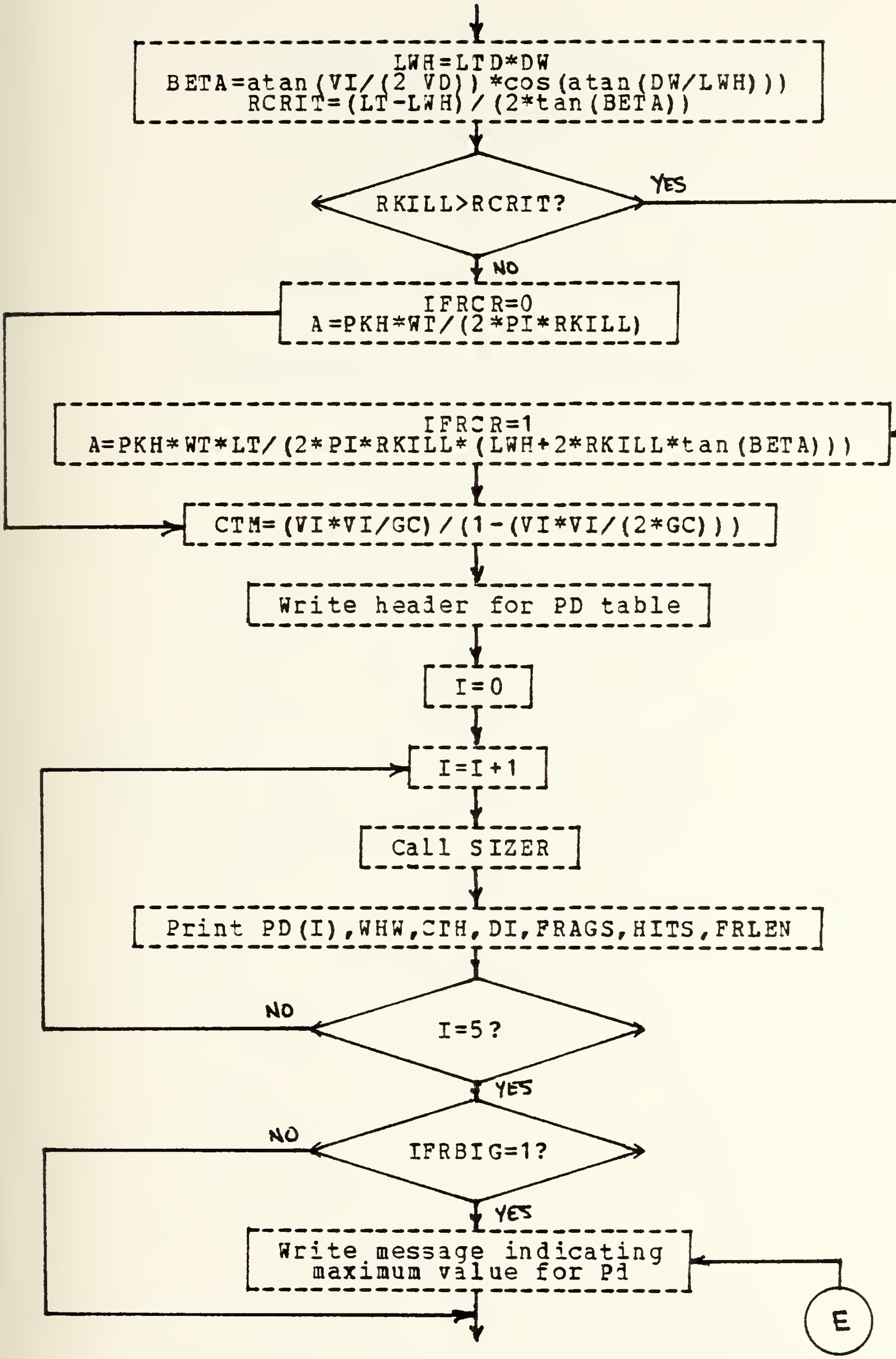
```
      XMAX=(9.0+XMININ)*SCALES                                          LPA00520
      XSPAN=XMAX-XMIN                                                   LPA00530
  135 CONTINUE                                                          LPA00540
C                                                                       LPA00550
C     LOCATE ORIGIN OF AXES                                             LPA00560
      CALL PLOT(2.,2.,-3)                                               LPA00570
C                                                                       LPA00580
C     SCALE X VALUES TO 9.0 INCH AXIS AND Y VALUES TO 7.0 INCH AXIS     LPA00590
C     AND PLOT THEM                                                     LPA00600
      X(1)=XMIN                                                         LPA00610
      X(2)=XMAX                                                         LPA00620
      X(3)=XMAX                                                         LPA00630
      X(4)=0.0                                                          LPA00640
      X(5)=0.0                                                          LPA00650
      Y(1)=YMAX                                                         LPA00660
      Y(2)=YMAX                                                         LPA00670
      Y(3)=YMIN                                                         LPA00680
      Y(4)=0.0                                                          LPA00690
      Y(5)=0.0                                                          LPA00700
      CALL SCALE(X,9.0,3,1)                                             LPA00710
      CALL SCALE(Y,7.0,3,1)                                             LPA00720
      CALL AXIS(0.,0.,'REFERENCE DIRECTION',-19,9.0,0.,XMIN,SCALES)     LPA00730
      CALL AXIS(0.,0.,' ',+1,7.0,90.,YMIN,SCALES)                       LPA00740
C                                                                       LPA00750
      DO 160 K=1,N                                                      LPA00760
      Z=I(K)                                                            LPA00770
C                                                                       LPA00780
C        PLOT TARGET PATH                                               LPA00790
         DO 140 J=1,500                                                 LPA00800
            X(J)=XT(J,K)                                                LPA00810
            Y(J)=YT(J,K)                                                LPA00820
            IF (J.EQ.Z) GO TO 145                                       LPA00830
  140    CONTINUE                                                       LPA00840
  145    X(Z+1)=XMIN                                                    LPA00850
         X(Z+2)=SCALES                                                  LPA00860
         Y(Z+1)=YMIN                                                    LPA00870
         Y(Z+2)=SCALES                                                  LPA00880
         CALL LINE(X,Y,Z,1,+Z,5)                                        LPA00890
C                                                                       LPA00900
C        PLOT MISSILE PATH                                              LPA00910
         DO 150 J=1,500                                                 LPA00920
            X(J)=XM(J,K)                                                LPA00930
            Y(J)=YM(J,K)                                                LPA00940
            IF (J.EQ.Z) GO TO 155                                       LPA00950
  150    CONTINUE                                                       LPA00960
  155    X(Z+1)=XMIN                                                    LPA00970
         X(Z+2)=SCALES                                                  LPA00980
         Y(Z+1)=YMIN                                                    LPA00990
```

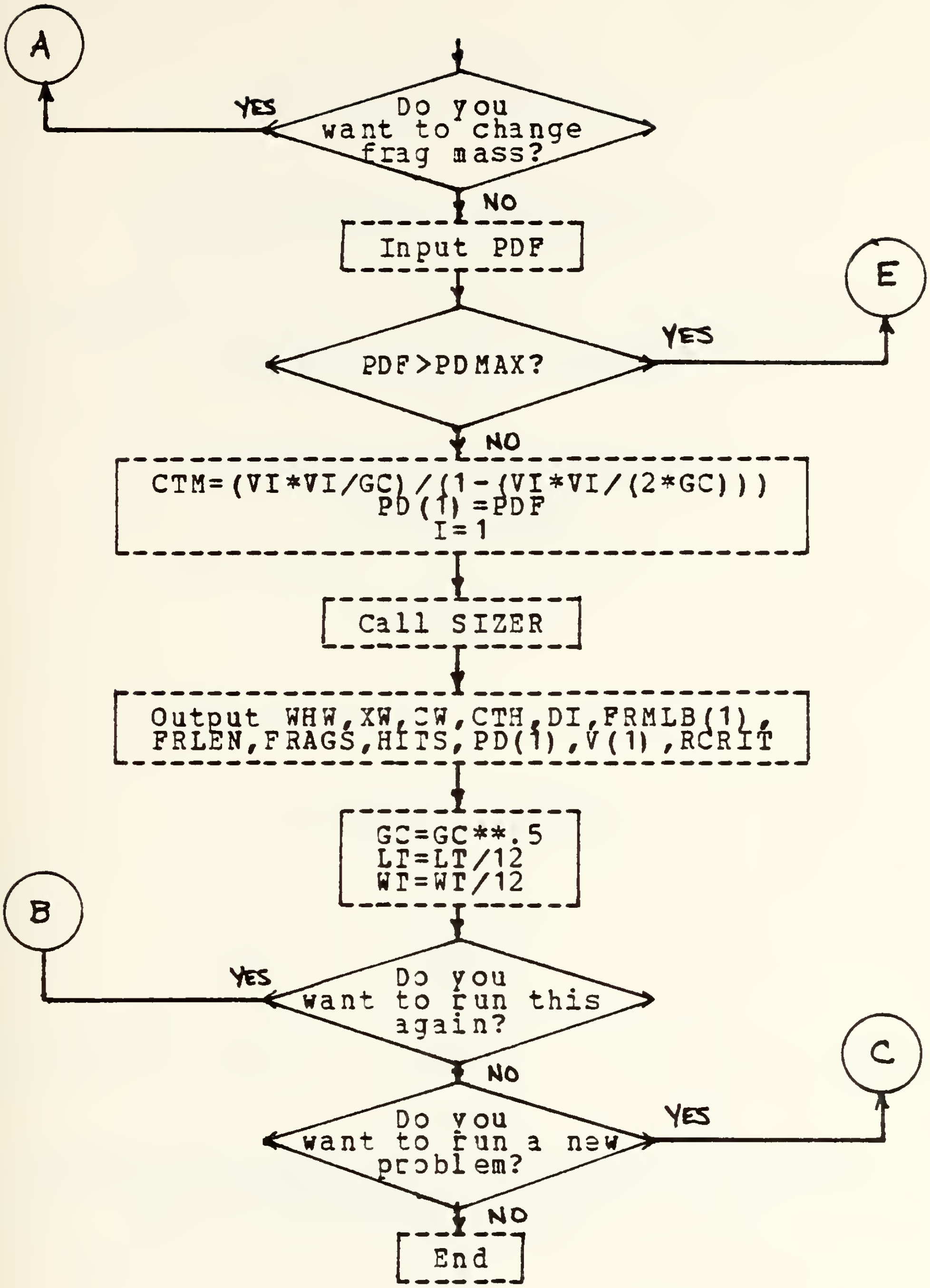
```
            Y(Z+2)=SCALES
            CALL LINE(X,Y,Z,1,+Z,0)
            XO=X(Z)/SCALES
            YO=Y(Z)/SCALES
            CALL NUMBER(XO,YO,0.1,SYMB(K),0.0,-1)
C
  160 CONTINUE
C
C       END OF PLOTTING
        CALL PLOT(0.,0.,+999)
        STOP
        END
/*
//GO.PLOTPARM DD *
 &PLOT SCALE=0.5  &END
/*
//GO.SYSIN DD *
```

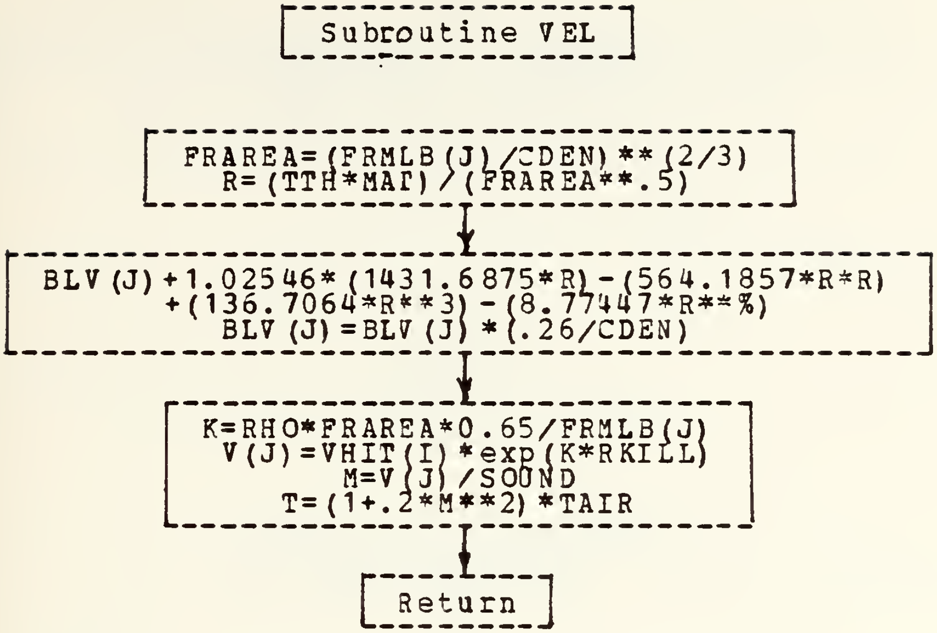
# APPENDIX C. WARHEAD DESIGN PROGRAM FLOWCHART

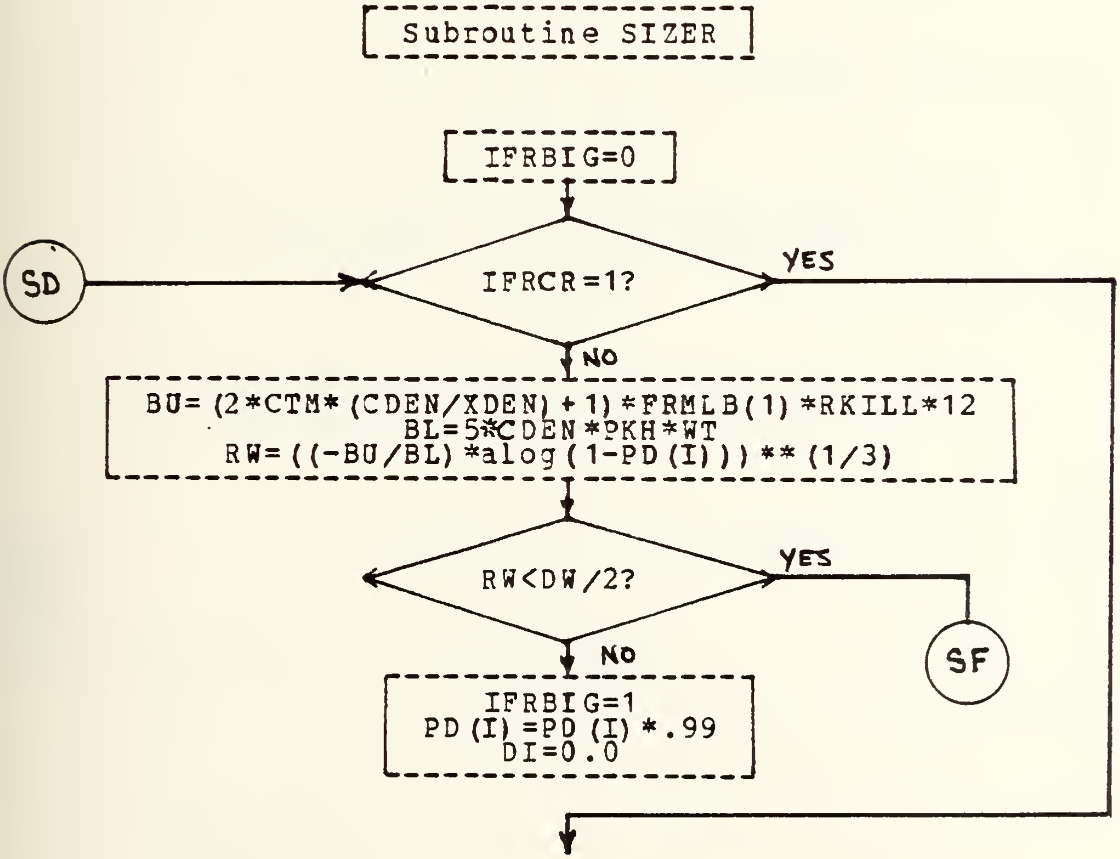

MAIN
Input XDEN,GC,VD,CDEN,RKILL,DW LTD,LT,WT,PKH,ALT,TTH,MAT
Present input data to user
B
Is it correct?
NO
C
YES
GC=GC*GC
LT=LT*12
WT=WT*12
RHO=.0023769*(exp(-.0000325*ALT)-.0172 *exp(.00001*(ALT-100000)))
TAIR=390
ALT<36000?
NO
YES
TAIR=518.688*(-.0000068917*ALT+1)
ALT>80000?
NO
TAIR=518.688*(.00000285*ALT+.5239)
SOUND=((TAIR/518.688)**.5)*1117.5874
Write header for velocity table
A

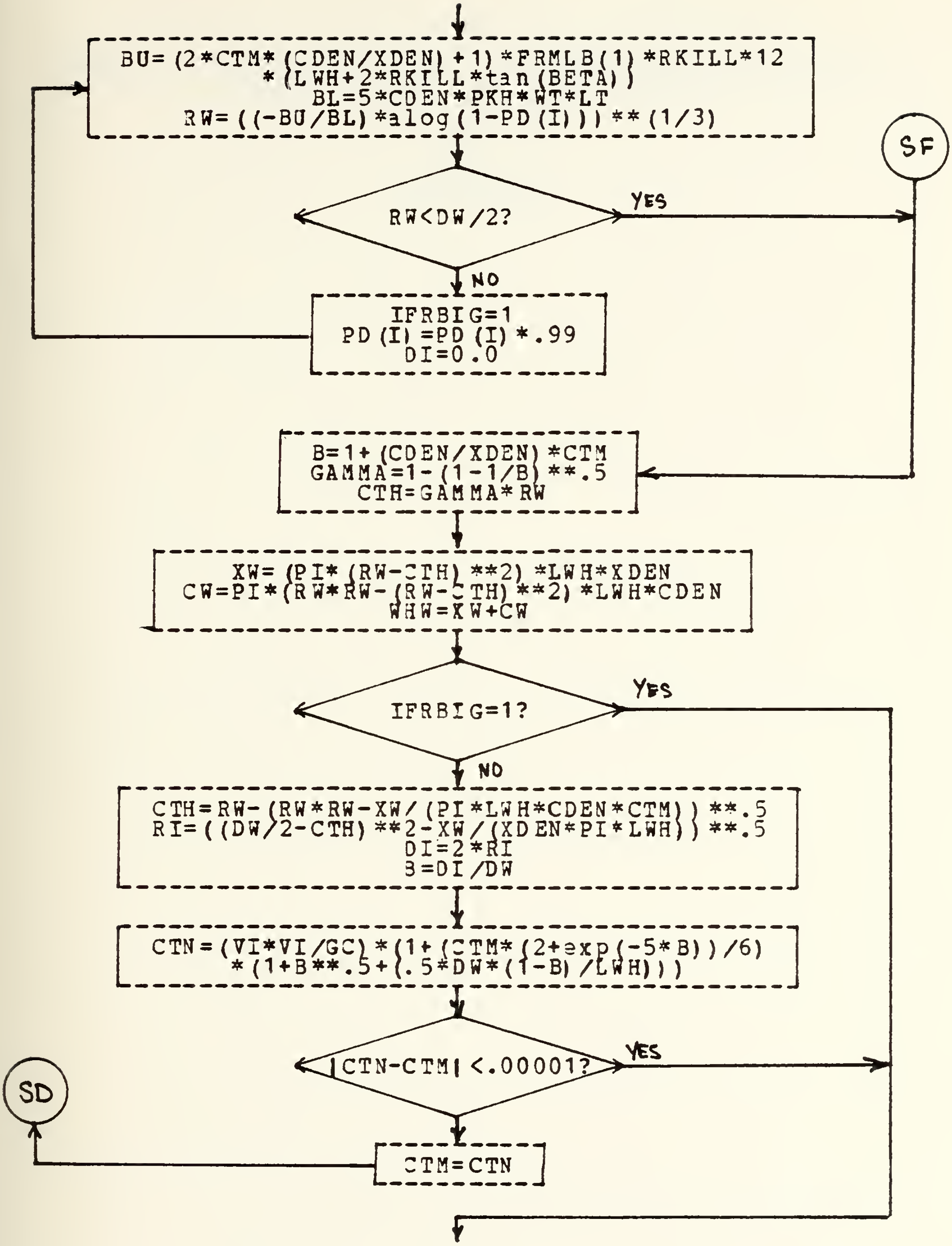

I=0
I=I+1
J=0
J=J+1
Call VEL
NO
J=6?
YES
Print VHIT(I),V(1),V(2),V(3),V(4),V(5),V(6)
NO
I=6?
YES
User want new RKILL?
NO
A
YES
Input RKILL
Input FRMLB(1),VHIT(1)
I=1
J=1
Call VEL


LWH=LTD*DW
BETA=atan(VI/(2 VD))*cos(atan(DW/LWH)))
RCRIT=(LT-LWH)/(2*tan(BETA))
RKILL>RCRIT?
YES
NO
IFRCR=0
A=PKH*WT/(2*PI*RKILL)
IFRCR=1
A=PKH*WT*LT/(2*PI*RKILL*(LWH+2*RKILL*tan(BETA)))
CTM=(VI*VI/GC)/(1-(VI*VI/(2*GC)))
Write header for PD table
I=0
I=I+1
Call SIZER
Print PD(I),WHW,CTH,DI,FRAGS,HITS,FRLEN
NO
I=5?
YES
NO
IFRBIG=1?
YES
Write message indicating maximum value for Pd
E


A
YES
Do you want to change frag mass?
NO
Input PDF
E
YES
PDF>PDMAX?
NO
CTM=(VI*VI/GC)/(1-(VI*VI/(2*GC)))
PD(1)=PDF
I=1
Call SIZER
Output WHW,XW,CW,CTH,DI,FRMLB(1),
FRLEN,FRAGS,HITS,PD(1),V(1),RCRIT
GC=GC**.5
LT=LT/12
WT=WT/12
B
YES
Do you want to run this again?
NO
C
YES
Do you want to run a new problem?
NO
End


Subroutine VEL
FRAREA=(FRMLB(J)/CDEN)**(2/3)
R=(TTH*MAΓ)/(FRAREA**.5)
BLV(J)+1.02546*(1431.6875*R)-(564.1857*R*R)
+(136.7064*R**3)-(8.77447*R**%)
BLV(J)=BLV(J)*(.26/CDEN)
K=RHO*FRAREA*0.65/FRMLB(J)
V(J)=VHIT(I)*exp(K*RKILL)
M=V(J)/SOUND
T=(1+.2*M**2)*TAIR
Return


Subroutine SIZER
IFRBIG=0
SD
IFRCR=1?
YES
NO
BU=(2*CTM*(CDEN/XDEN)+1)*FRMLB(1)*RKILL*12
BL=5*CDEN*PKH*WT
RW=((-BU/BL)*alog(1-PD(I)))**(1/3)
RW<DW/2?
YES
SF
NO
IFRBIG=1
PD(I)=PD(I)*.99
DI=0.0



```
BU=(2*CTM*(CDEN/XDEN)+1)*FRMLB(1)*RKILL*12
*(LWH+2*RKILL*tan(BETA))
BL=5*CDEN*PKH*WT*LT
RW=((-BU/BL)*alog(1-PD(I)))**(1/3)

RW<DW/2?

IFRBIG=1
PD(I)=PD(I)*.99
DI=0.0

B=1+(CDEN/XDEN)*CTM
GAMMA=1-(1-1/B)**.5
CTH=GAMMA*RW

XW=(PI*(RW-CTH)**2)*LWH*XDEN
CW=PI*(RW*RW-(RW-CTH)**2)*LWH*CDEN
WHW=XW+CW

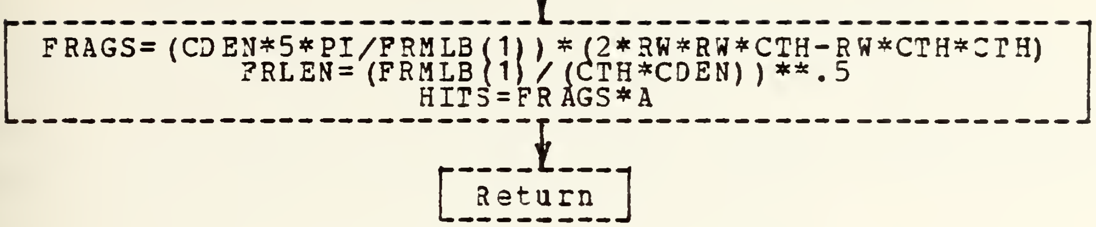
IFRBIG=1?

CTH=RW-(RW*RW-XW/(PI*LWH*CDEN*CTM))**.5
RI=((DW/2-CTH)**2-XW/(XDEN*PI*LWH))**.5
DI=2*RI
B=DI/DW

CTN=(VI*VI/GC)*(1+(CTM*(2+exp(-5*B))/6)
*(1+B**.5+(.5*DW*(1-B)/LWH)))

|CTN-CTM|<.00001?

CTM=CTN
```



```
FRAGS=(CDEN*5*PI/FRMLB(1))*(2*RW*RW*CTH-RW*CTH*CTH)
FRLEN=(FRMLB(1)/(CTH*CDEN))**.5
HITS=FRAGS*A
```

# APPENDIX D. WARHEAD DESIGN PROGRAM LISTING

This program has two major sections; the executive routine and the FORTRAN IV computational program. The executive routine establishes the required file definitions and initiates operation of the computational program.

The computational program, LBOMB FORTRAN, consists of four subprogram divisions. The MAIN program accepts the input data, calculates the atmospheric characteristics, and formats and displays the output to the user and sends it to the printer file. Subroutine VEL calculates the initial velocity required to propel a given mass a specified distance through the atmosphere with a particular residual velocity remaining. It also determines the ballistic limit velocities for the situation. Subroutine SIZER sizes the warhead for a given Pd value. It also produces the charge-to-mass ratio, the number of fragments, the fragment size, and the average number of hits received by the target. Subroutine SCREEN prompts the user to clear the terminal screen for proper positioning of the displayed data.

```
FILE: LBOMB    EXEC       A    NAVAL POSTGRADUATE SCHOOL

FILEDEF 08 DISK LBOMB OUTPUT A0 (PERM
&BEGTYPE

YOU WILL HAVE THE OPTION TO OBTAIN A HARDCOPY PRINTOUT
OF THE LAST SOLUTION THAT YOU SOLVE.  YOU MAY RERUN THE
PROGRAM AS OFTEN AS YOU WISH BUT THE LAST RUN IS THE RUN
THAT IS RECORDED.

&END
LOAD LBOMB
START
&BEGTYPE

TO OBTAIN A HARDCOPY PRINTOUT OF THE RESULTS, TYPE
"PRINT LBOMB OUTPUT" AND ENTER.  THE OUTPUT WILL BE
PRINTED ON THE VM PRINTER IN ROOM 140 AND WILL BE
IDENTIFIED BY YOUR USER NUMBER AND LABEL NAME.  IT
USUALLY REQUIRES SEVERAL MINUTES TO OBTAIN THE
PRINTOUT.

&END
```

```
C LBOMB
C WARHEAD SIZING PROGRAM
C LT. M.D.SULLIVAN,USN                           3 JUNE 1981
C PROGRAM COORDINATOR:  PROFESSOR GERALD LINDSEY,  DEPT OF AERONAUTICS
C
      REAL FRMLB,VHIT,PD,BLV,CDEN,TTH,MAT,RHO,RKILL,SOUND,TAIR,V,T,XDEN
      REAL CTM,PKH,WT,DW,CTH,CTN,WHW,FRAGS,FRLEN,HITS,A,GC,VD,LTD,LT
      REAL ALT,LWH,BETA,VI,RCRIT,DI,PDF
      INTEGER I,J,K,IWANT,IFRCR,FRMGR,IFRBIG
      DIMENSION FRMLB(6),VHIT(6),PD(5),BLV(6),V(6)
      DIMENSION FRMGR(6)
      DATA FRMLB/.0071428,.0142857,.0214285,.0285714,.0357142,.0428571/
      DATA VHIT/1000.,2000.,3000.,4000.,5000.,6000./
      DATA PD/.999,.99,.98,.95,.90/
      DATA FRMGR/50,100,150,200,250,300/
      PI=3.1415926
C
  100 FORMAT (F15.5)
  110 FORMAT (I2)
  120 FORMAT (I1)
 1000 CALL SCREEN
      IFBACK=0
      WRITE (6,1010)
 1010 FORMAT (1X,'INPUT THE FOLLOWING DATA AS DECIMAL NUMBERS ONLY:'/)
 6001 WRITE (6,1020)
 1020 FORMAT (1X,' 1) INPUT EXPLOSIVE DENSITY (LB/CU.IN):')
      READ (5,100) XDEN
      IF (IFBACK.EQ.1) GO TO 1500
 6002 WRITE (6,1030)
 1030 FORMAT (1X,' 2) INPUT EXPLOSIVE GURNEY CONSTANT (FT/SEC):')
      READ (5,100) GC
      IF (IFBACK.EQ.1) GO TO 1500
 6003 WRITE (6,1040)
 1040 FORMAT (1X,' 3) INPUT EXPLOSIVE DETONATION VELOCITY (FT/SEC):')
      READ (5,100) VD
      IF (IFBACK.EQ.1) GO TO 1500
 6004 WRITE (6,1050)
 1050 FORMAT (1X,' 4) INPUT CASE MATERIAL DENSITY (LB/CU.IN):')
      READ (5,100) CDEN
      IF (IFBACK.EQ.1) GO TO 1500
 6005 WRITE (6,1060)
 1060 FORMAT (1X,' 5) INPUT DESIRED KILL RADIUS (FT):')
      READ (5,100) RKILL
      IF (IFBACK.EQ.1) GO TO 1500
 6006 WRITE (6,1070)
```

```
 1070 FORMAT (1X,' 6) INPUT WARHEAD DIAMETER (IN):')                   LB000520
      READ (5,100) DW                                                  LB000530
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000540
 6007 WRITE (6,1080)                                                   LB000550
 1080 FORMAT (1X,' 7) INPUT WARHEAD LENGTH-TO-DIAMETER RATIO:')        LB000560
      READ (5,100) LTD                                                 LB000570
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000580
 6008 WRITE (6,1090)                                                   LB000590
 1090 FORMAT (1X,' 8) INPUT TARGET LENGTH (FT):')                      LB000600
      READ (5,100) LT                                                  LB000610
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000620
 6009 WRITE (6,1100)                                                   LB000630
 1100 FORMAT (1X,' 9) INPUT TARGET WIDTH (FT):')                       LB000640
      READ (5,100) WT                                                  LB000650
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000660
 6010 WRITE (6,1110)                                                   LB000670
 1110 FORMAT (1X,'10) INPUT TARGET VULNERABILITY, P(K/H):')            LB000680
      READ (5,100) PKH                                                 LB000690
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000700
 6011 WRITE (6,1120)                                                   LB000710
 1120 FORMAT (1X,'11) INPUT TARGET ALTITUDE (FT):')                    LB000720
      READ (5,100) ALT                                                 LB000730
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000740
 6012 WRITE (6,1130)                                                   LB000750
 1130 FORMAT (1X,'12) INPUT TARGET SKIN THICKNESS (IN):')              LB000760
      READ (5,100) TTH                                                 LB000770
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000780
 6013 WRITE (6,1140)                                                   LB000790
 1140 FORMAT (1X,'13) INPUT SKIN MATERIAL CODE:  1.0=ALUMINUM'/,       LB000800
     *32X,'2.0=FIBERGLASS/KEVLAR'/,                                    LB000810
     *32X,'3.0=STEEL')                                                 LB000820
      READ (5,100) MAT                                                 LB000830
      IF (IFBACK.EQ.1) GO TO 1500                                      LB000840
C                                                                      LB000850
 1500 CALL SCREEN                                                      LB000860
      REWIND 08                                                        LB000870
      IFBACK=1                                                         LB000880
      WRITE (6,1510) XDEN,GC,VD,CDEN,RKILL,DW,LTD                      LB000890
      WRITE (8,1510) XDEN,GC,VD,CDEN,RKILL,DW,LTD                      LB000900
 1510 FORMAT (1X,'  THE FOLLOWING IS A SUMMARY OF THE INPUT DATA:'/,   LB000910
     *1X,'01) EXPLOSIVE DENSITY',T40,F10.5,' LB/CU.IN'/,               LB000920
     *1X,'02) EXPLOSIVE GURNEY CONSTANT',T40,F10.2,' FT/SEC'/,         LB000930
     *1X,'03) EXPLOSIVE DETONATION VELOCITY',T40,F10.2,' FT/SEC'/,     LB000940
     *1X,'04) CASE MATERIAL DENSITY',T40,F10.4,' LB/CU.IN'/,           LB000950
     *1X,'05) DESIRED KILL RADIUS',T40,F10.1,' FEET'/,                 LB000960
     *1X,'06) WARHEAD DIAMETER',T40,F10.2,' INCHES'/,                  LB000970
     *1X,'07) WARHEAD LENGTH-TO-DIAMETER RATIO',T40,F10.2)             LB000980
      WRITE (6,1520) LT,WT,PKH,ALT,TTH                                 LB000990
```

```
      WRITE (8,1520) LT,WT,PKH,ALT,TTH                                  LB001000
 1520 FORMAT (1X,'08) TARGET LENGTH',T40,F10.2,' FEET'/,                LB001010
     *1X,'09) TARGET WIDTH',T40,F10.2,' FEET'/,                         LB001020
     *1X,'10) TARGET VULNERABILITY, P(K/H)',T40,F10.3/,                 LB001030
     *1X,'11) TARGET ALTITUDE',T40,F10.0,' FEET'/,                      LB001040
     *1X,'12) TARGET SKIN THICKNESS',T40,F10.3,' INCHES')               LB001050
      IF (MAT.EQ.1.) WRITE (6,1530)                                     LB001060
      IF (MAT.EQ.1.) WRITE (8,1530)                                     LB001070
 1530 FORMAT (1X,'13) TARGET SKIN MATERIAL',T40,'  ALUMINUM')           LB001080
      IF (MAT.EQ.2.) WRITE (6,1540)                                     LB001090
      IF (MAT.EQ.2.) WRITE (8,1540)                                     LB001100
 1540 FORMAT (1X,'13) TARGET SKIN MATERIAL',T40,'FIBERGLASS')           LB001110
      IF (MAT.EQ.3.) WRITE (6,1550)                                     LB001120
      IF (MAT.EQ.3.) WRITE (8,1550)                                     LB001130
 1550 FORMAT (1X,'13) TARGET SKIN MATERIAL',T40,'     STEEL')           LB001140
      WRITE (6,1560)                                                    LB001150
 1560 FORMAT (/1X,'IS THIS INPUT CORRECT?  IF YES, ENTER "00",'/,       LB001160
     *1X,'IF NO, ENTER THE TWO-DIGIT NUMBER OF THE WRONG ENTRY.')       LB001170
      READ (5,110) IGOTO                                                LB001180
      IF (IGOTO.EQ.00) GO TO 1600                                       LB001190
      GO TO (6001,6002,6003,6004,6005,6006,6007,6008,6009,6010,6011,6012LB001200
     *,6013), IGOTO                                                     LB001210
C                                                                       LB001220
 1600 GC=GC*GC                                                          LB001230
      LT=LT*12.                                                         LB001240
      WT=WT*12.                                                         LB001250
C                                                                       LB001260
      RHO=.0023769*(EXP(-.0000325*ALT)-.0172*EXP(.00001*(ALT-100000.))) LB001270
      TAIR=390.                                                         LB001280
      IF (ALT.LT.36000.) TAIR=518.688*(-.0000068917*ALT+1.)             LB001290
      IF (ALT.GT.80000.) TAIR=518.688*(.00000285*ALT+.5239)             LB001300
      SOUND=((TAIR/518.688)**.5)*1117.5874                              LB001310
C                                                                       LB001320
 1990 CALL SCREEN                                                       LB001330
      VHIT(1)=1000.                                                     LB001340
      FRMLB(1)=.0071428                                                 LB001350
      WRITE (6,2000) RKILL                                              LB001360
      WRITE (8,2000) RKILL                                              LB001370
 2000 FORMAT (/1X,'INITIAL VELOCITY TABLE FOR',F6.1,' FT KILL RADIUS'/, LB001380
     *2X,'IMPACT',25X,'FRAGMENT MASSES'/,                               LB001390
     *1X,'VELOCITY',T14,'50 GR.',T23,'100 GR.',T33,'150 GR.',T43,'200 GRLB001400
     *.',T53,'250 GR.',T63,'300 GR.')                                   LB001410
      DO 2030 I=1,6                                                     LB001420
         DO 2010 J=1,6                                                  LB001430
            CALL VEL (FRMLB,VHIT,BLV,V,CDEN,TTH,MAT,RHO,RKILL,SOUND,    LB001440
     *      TAIR,T,I,J)                                                 LB001450
 2010    CONTINUE                                                       LB001460
         WRITE (6,2020) VHIT(I),(V(K),K=1,6)                            LB001470
```

```
         WRITE (8,2020) VHIT(I),(V(K),K=1,6)                            LB001480
 2020    FORMAT (3X,F5.0,6(4X,F6.0))                                    LB001490
 2030 CONTINUE                                                          LB001500
      WRITE (6,2035) (BLV(I),I=1,6)                                     LB001510
      WRITE (8,2035) (BLV(I),I=1,6)                                     LB001520
 2035 FORMAT (1X,'BALLISTIC'/,1X,'LIMIT',7X,F5.0,5(5X,F5.0))            LB001530
      WRITE (6,2045)                                                    LB001540
 2045 FORMAT (/1X,'DO YOU WANT A NEW KILL RADIUS? (1=YES,0=NO)')        LB001550
      READ (5,120) IWANT                                                LB001560
      IF (IWANT.EQ.0) GO TO 2049                                        LB001570
      WRITE (6,2046)                                                    LB001580
 2046 FORMAT (1X,'INPUT NEW KILL RADIUS (FEET, DECIMAL):')              LB001590
      READ (5,100) RKILL                                                LB001600
      GO TO 1990                                                        LB001610
 2049 WRITE (6,2050)                                                    LB001620
 2050 FORMAT (1X,'INPUT DESIRED FRAGMENT MASS (GRAINS, DECIMAL):')      LB001630
      READ (5,100) FRMLB(1)                                             LB001640
      WRITE (8,2051) FRMLB(1)                                           LB001650
 2051 FORMAT (/1X,'FRAGMENT MASS........',F6.1,' GRAINS')               LB001660
      FRMLB(1)=FRMLB(1)*.000142856973                                   LB001670
      WRITE (6,2060)                                                    LB001680
 2060 FORMAT (1X,'INPUT DESIRED IMPACT VELOCITY (FT/SEC, DECIMAL):')    LB001690
      READ (5,100) VHIT(1)                                              LB001700
      WRITE (8,2061) VHIT(1)                                            LB001710
 2061 FORMAT (1X,'IMPACT VELOCITY......',F6.0,' FT/SEC'/)               LB001720
      CALL SCREEN                                                       LB001730
      I=1                                                               LB001740
      J=1                                                               LB001750
      CALL VEL (FRMLB,VHIT,BLV,V,CDEN,TTH,MAT,RHO,RKILL,SOUND,TAIR,T,I,JLB001760
     *)                                                                 LB001770
      VI=V(J)                                                           LB001780
C                                                                       LB001790
 2100 CONTINUE                                                          LB001800
      LWH=LTD*DW                                                        LB001810
      BETA=ATAN(VI/(2.*VD)*COS(ATAN(DW/LWH)))                           LB001820
      RCRIT=(LT-LWH)/(2.*TAN(BETA))                                     LB001830
      IF (RKILL.GT.RCRIT) GO TO 2105                                    LB001840
      IFRCR=0                                                           LB001850
      A=PKH*WT/(2.*PI*RKILL)                                            LB001860
      GO TO 2110                                                        LB001870
 2105 IFRCR=1                                                           LB001880
      A=PKH*WT*LT/(2.*PI*RKILL*(LWH+2.*RKILL*TAN(BETA)))                LB001890
C                                                                       LB001900
 2110 CONTINUE                                                          LB001910
      CTM=(VI*VI/GC)/(1.-(VI*VI/(2.*GC)))                               LB001920
 2115 CONTINUE                                                          LB001930
      WRITE (6,2120)                                                    LB001940
      WRITE (8,2120)                                                    LB001950
```

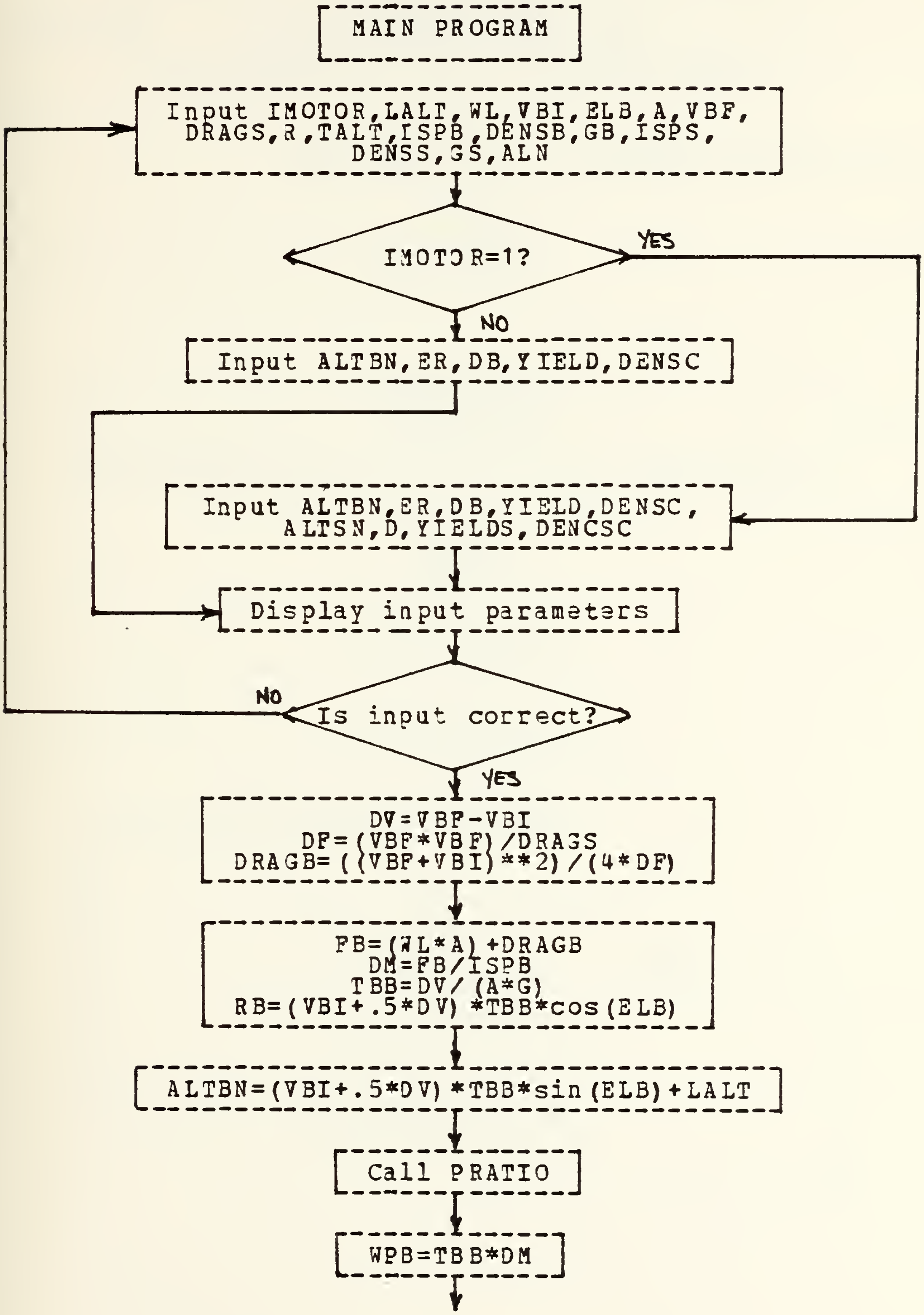
```
2120 FORMAT (T13,'WARHEAD',T25,'CASE',T36,'CORE',T43,'---------FRAGMENTLB001960
    *S---------'/,                                                      LB001970
    *6X,'PD',T14,'WEIGHT',T23,'THICKNESS',T34,'DIAMETER',T44,           LB001980
    *'NUMBER',T53,'ON TARGET',T64,'LENGTH')                             LB001990
     DO 2200 I=1,5                                                      LB002000
        CALL SIZER (FRMLB,PD,CDEN,XDEN,CTM,RKILL,PKH,WT,DW,CTH,GC,WHW,  LB002010
    *   LT,VI,DI,LWH,BETA,FRAGS,FRLEN,HITS,A,XW,CW,IFRBIG,IFRCR,I)      LB002020
        WRITE (6,2160) PD(I),WHW,CTH,DI,FRAGS,HITS,FRLEN                LB002030
        WRITE (8,2160) PD(I),WHW,CTH,DI,FRAGS,HITS,FRLEN                LB002040
2200 CONTINUE                                                           LB002050
2160 FORMAT (1X,F8.3,6(2X,F8.2))                                        LB002060
2205 IF (PD(1).LT..999) WRITE (6,2210)                                  LB002070
     IF (PD(1).LT..999) WRITE (8,2210)                                  LB002080
2210 FORMAT (1X,'THE FIRST PD TERM IS THE HIGHEST ATTAINABLE WITH THE GLB002090
    *IVEN'/,1X,'KILL RADIUS AND FRAGMENT SIZE.')                        LB002100
2215 WRITE (6,2220)                                                     LB002110
2220 FORMAT (1X,'DO YOU WANT TO CHANGE YOUR FRAGMENT SIZE? (1=YES,0=NO)LB002120
    *')                                                                 LB002130
     READ (5,120) IWANT                                                 LB002140
     IF (IWANT.EQ.1) GO TO 1990                                         LB002150
2225 WRITE (6,2230)                                                     LB002160
2230 FORMAT (1X,'INPUT DESIRED PD (DECIMAL):')                          LB002170
     READ (5,100) PDF                                                   LB002180
     IF (PDF.LT.PD(1)) GO TO 2228                                       LB002190
     WRITE (6,2229)                                                     LB002200
2229 FORMAT (1X,'TOO LARGE   PD CANNOT BE GREATER THAN THE FIRST ONE ONLB002210
    * THE LIST ABOVE '/,1X,'TRY AGAIN')                                 LB002220
     GO TO 2225                                                         LB002230
2228 CALL SCREEN                                                        LB002240
     WRITE (8,2231) PDF                                                 LB002250
2231 FORMAT (/1X,'KILL PROBABILITY.....',F6.3/)                         LB002260
     CTM=(VI*VI/GC)/(1.-(VI*VI/(2.*GC)))                                LB002270
     PD(1)=PDF                                                          LB002280
     I=1                                                                LB002290
     CALL SIZER (FRMLB,PD,CDEN,XDEN,CTM,RKILL,PKH,WT,DW,CTH,GC,WHW,     LB002300
    *LT,VI,DI,LWH,BETA,FRAGS,FRLEN,HITS,A,XW,CW,IFRBIG,IFRCR,I)         LB002310
     FRMLB(1)=FRMLB(1)/.000142856973                                    LB002320
     WRITE (6,2300)                                                     LB002330
     WRITE (8,2300)                                                     LB002340
2300 FORMAT (1X,'WARHEAD DESCRIPTION---------------------------------')LB002350
     WRITE (6,2310) WHW,XW,CW,CTH,DI,FRMLB(1)                           LB002360
     WRITE (8,2310) WHW,XW,CW,CTH,DI,FRMLB(1)                           LB002370
2310 FORMAT (/4X,'WARHEAD WEIGHT',T35,F8.2,' POUNDS'/,                  LB002380
    *4X,'EXPLOSIVE WEIGHT',T35,F8.2,' POUNDS'/,                         LB002390
    *4X,'CASE WEIGHT',T35,F8.2,' POUNDS'/,                              LB002400
    *4X,'CASE THICKNESS',T35,F8.4,' INCHES'/,                           LB002410
    *4X,'CORE DIAMETER',T35,F8.2,' INCHES'/,                            LB002420
    *4X,'FRAGMENT WEIGHT',T35,F8.2,' GRAINS')                           LB002430
```

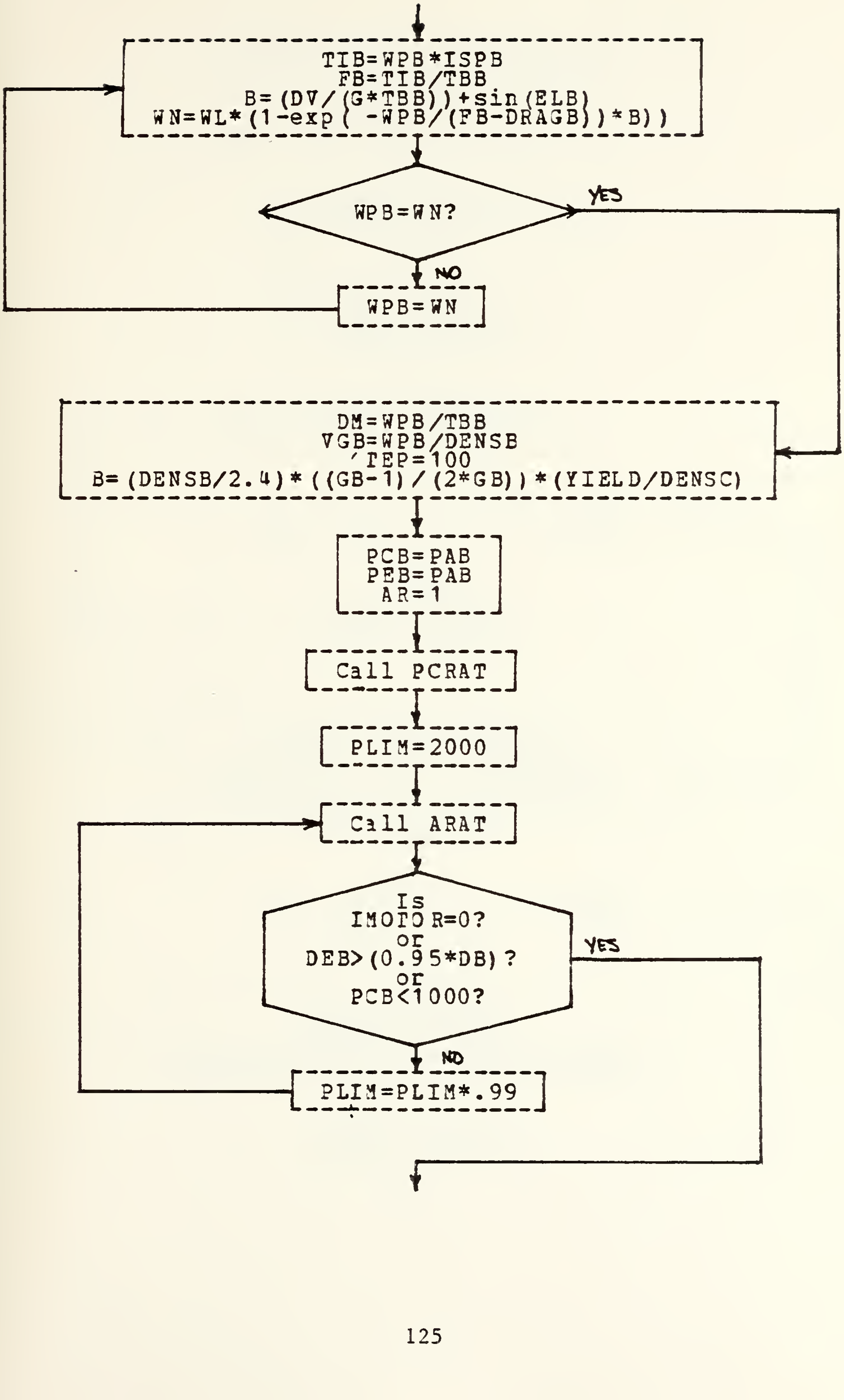
```
      WRITE (6,2320) FRLEN,FRLEN,CTH,FRAGS,HITS,PD(1),V(1),RCRIT         LB002440
      WRITE (8,2320) FRLEN,FRLEN,CTH,FRAGS,HITS,PD(1),V(1),RCRIT         LB002450
 2320 FORMAT (4X,'FRAGMENT DIMENSIONS',T26,F5.3,' X ',F5.3,' X ',F5.3,   LB002460
     *' INCHES'/,4X,'NUMBER OF FRAGMENTS',T35,F8.0/,                     LB002470
     *4X,'NUMBER OF HITS ON TARGET',T35,F8.0/,                           LB002480
     *4X,'PROBABILITY OF KILL (PD)',T35,F8.3/,                           LB002490
     *4X,'INITIAL FRAGMENT VELOCITY',T35,F8.1,' FT/SEC'/,                LB002500
     *4X,'CRITICAL MISS DISTANCE',T35,F8.1,' FEET'/)                     LB002510
C                                                                        LB002520
      GC=GC**.5                                                          LB002530
      LT=LT/12.                                                          LB002540
      WT=WT/12.                                                          LB002550
      FRMLB(1)=.0071428                                                  LB002560
      VHIT(1)=1000.                                                      LB002570
      PD(1)=.999                                                         LB002580
C                                                                        LB002590
      WRITE (6,2400)                                                     LB002600
 2400 FORMAT (1X,'DO YOU WANT TO RUN THIS PROBLEM AGAIN? (1=YES,0=NO)') LB002610
      READ (5,120) IWANT                                                 LB002620
      IF (IWANT.EQ.1) GO TO 1500                                         LB002630
      WRITE (6,2410)                                                     LB002640
 2410 FORMAT (1X,'DO YOU WANT TO RUN A NEW PROBLEM? (1=YES,0=NO)')       LB002650
      READ (5,120) IWANT                                                 LB002660
      IF (IWANT.EQ.1) GO TO 1000                                         LB002670
      CALL SCREEN                                                        LB002680
      RETURN                                                             LB002690
      END                                                                LB002700
C                                                                        LB002710
C                                                                        LB002720
C                                                                        LB002730
C                                                                        LB002740
      SUBROUTINE VEL (FRMLB,VHIT,BLV,V,CDEN,TTH,MAT,RHO,RKILL,SOUND,     LB002750
     *TAIR,T,I,J)                                                        LB002760
      REAL FRAREA,FRMLB,CDEN,R,TTH,MAT,BLV,K,RHO,V,VHIT,RKILL,M,SOUND    LB002770
      REAL T,TAIR                                                        LB002780
      DIMENSION FRMLB(6),BLV(6),V(6),VHIT(6)                             LB002790
C                                                                        LB002800
      FRAREA=(FRMLB(J)/CDEN)**(2./3.)                                    LB002810
      R=(TTH*MAT)/(FRAREA**.5)                                           LB002820
      BLV(J)=1.02546+(1431.6875*R)-(564.1857*R*R)+(136.7064*R**3.)-(8.77LB002830
     *447*R**4.)                                                         LB002840
      BLV(J)=BLV(J)*(.26/CDEN)                                           LB002850
      K=RHO*FRAREA*0.65/FRMLB(J)                                         LB002860
      V(J)=VHIT(I)*EXP(K*RKILL)                                          LB002870
      M=V(J)/SOUND                                                       LB002880
      T=(1.+.2*M**2.)*TAIR                                               LB002890
      RETURN                                                             LB002900
      END                                                                LB002910
```

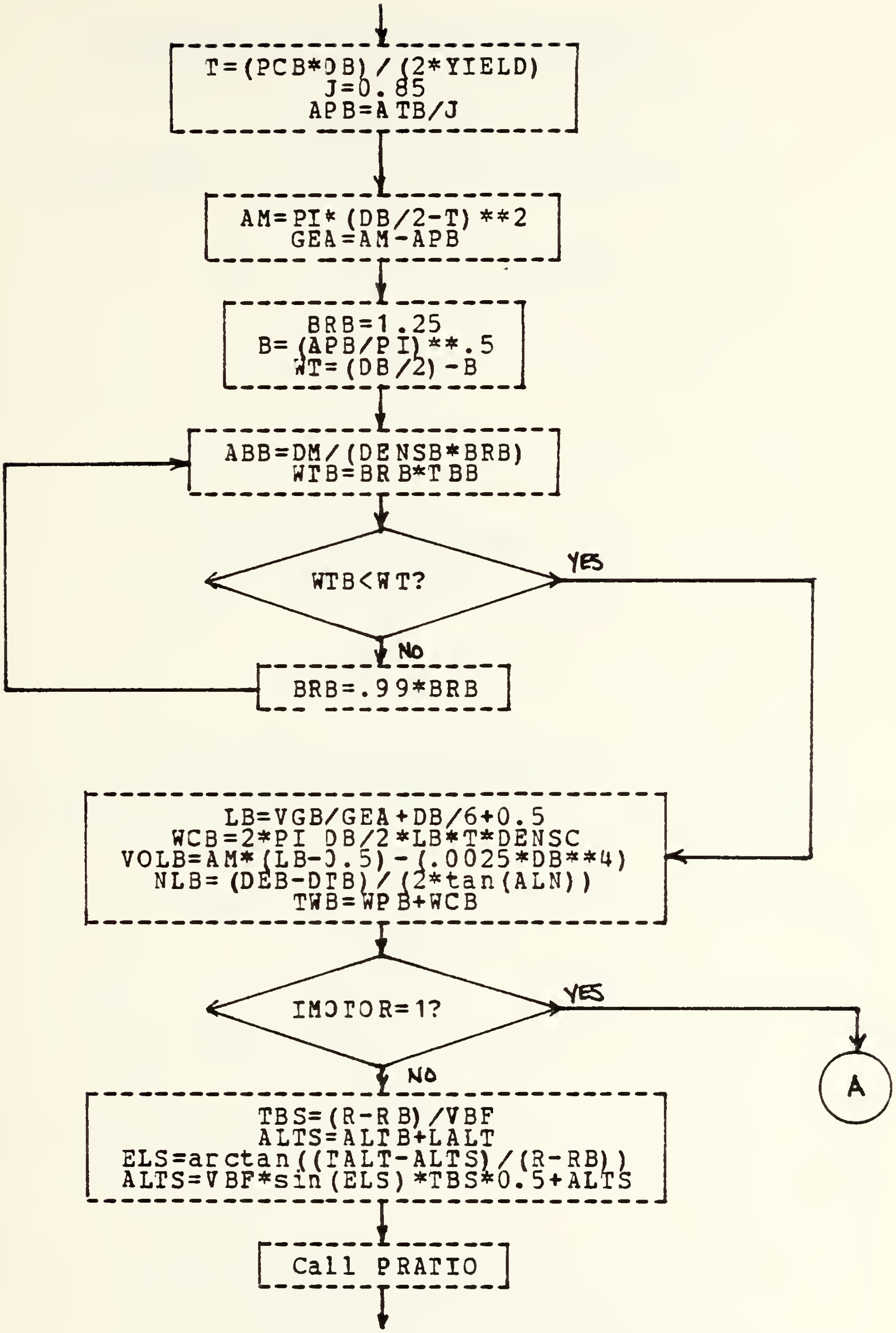
```
C                                                                       LB002920
C                                                                       LB002930
C                                                                       LB002940
C                                                                       LB002950
      SUBROUTINE SIZER (FRMLB,PD,CDEN,XDEN,CTM,RKILL,PKH,WT,DW,CTH,     LB002960
     *GC,WHW,LT,VI,DI,LWH,BETA,FRAGS,FRLEN,HITS,A,XW,CW,IFRBIG,IFRCR,I) LB002970
      REAL PI,BU,BL,CDEN,XDEN,CTM,RKILL,FRMLB,PKH,WT,GAMMA,B,LT         LB002980
      REAL RW,PD,DW,DI,CTH,XW,CW,LWH,WHW,RI,CTN,VI,GC,FRAGS,FRLEN,HITS  LB002990
      INTEGER IFRBIG,IFRCR,I                                            LB003000
      DIMENSION FRMLB(6),PD(5)                                          LB003010
C                                                                       LB003020
      PI=3.1415926                                                      LB003030
      IFRBIG=0                                                          LB003040
   10 IF (IFRCR.EQ.1) GO TO 25                                          LB003050
      BU=(2.*CTM*(CDEN/XDEN)+1.)*FRMLB(1)*RKILL*12.                     LB003060
      BL=5.*CDEN*PKH*WT                                                 LB003070
   20 RW=((-BU/BL)*ALOG(1.-PD(I)))**(1./3.)                             LB003080
      IF (RW.LT.DW/2.) GO TO 30                                         LB003090
      IFRBIG=1                                                          LB003100
      PD(I)=PD(I)*.99                                                   LB003110
      DI=0.0                                                            LB003120
      GO TO 20                                                          LB003130
   25 BU=(2.*CTM*(CDEN/XDEN)+1.)*FRMLB(1)*RKILL*12.*(LWH+2.*RKILL*TAN(BELB003140
     *TA))                                                              LB003150
      BL=5.*CDEN*PKH*WT*LT                                              LB003160
   26 RW=((-BU/BL)*ALOG(1.-PD(I)))**(1./3.)                             LB003170
      IF (RW.LT.DW/2.) GO TO 30                                         LB003180
      IFRBIG=1                                                          LB003190
      PD(I)=PD(I)*.99                                                   LB003200
      DI=0.0                                                            LB003210
      GO TO 26                                                          LB003220
   30 CONTINUE                                                          LB003230
      B=1.+(CDEN/XDEN)*CTM                                              LB003240
      GAMMA=1.-(1.-1./B)**.5                                            LB003250
      CTH=GAMMA*RW                                                      LB003260
      XW=(PI*(RW-CTH)**2.)*LWH*XDEN                                     LB003270
      CW=PI*(RW*RW-(RW-CTH)**2.)*LWH*CDEN                               LB003280
      WHW=XW+CW                                                         LB003290
      IF (IFRBIG.EQ.1) GO TO 50                                         LB003300
      CTH=RW-(RW*RW-XW/(PI*LWH*CDEN*CTM))**.5                           LB003310
      RI=((DW/2.-CTH)**2.-XW/(XDEN*PI*LWH))**.5                         LB003320
      DI=2*RI                                                           LB003330
      B=DI/DW                                                           LB003340
   40 CTN=(VI*VI/GC)*(1.+(CTM*(2.+EXP(-5.*B))/6.)*(1.+B**.5+(.5*DW*(1.-BLB003350
     *)/LWH)))                                                          LB003360
      IF (ABS(CTN-CTM).LT..00001) GO TO 50                              LB003370
      CTM=CTN                                                           LB003380
      GO TO 10                                                          LB003390
```

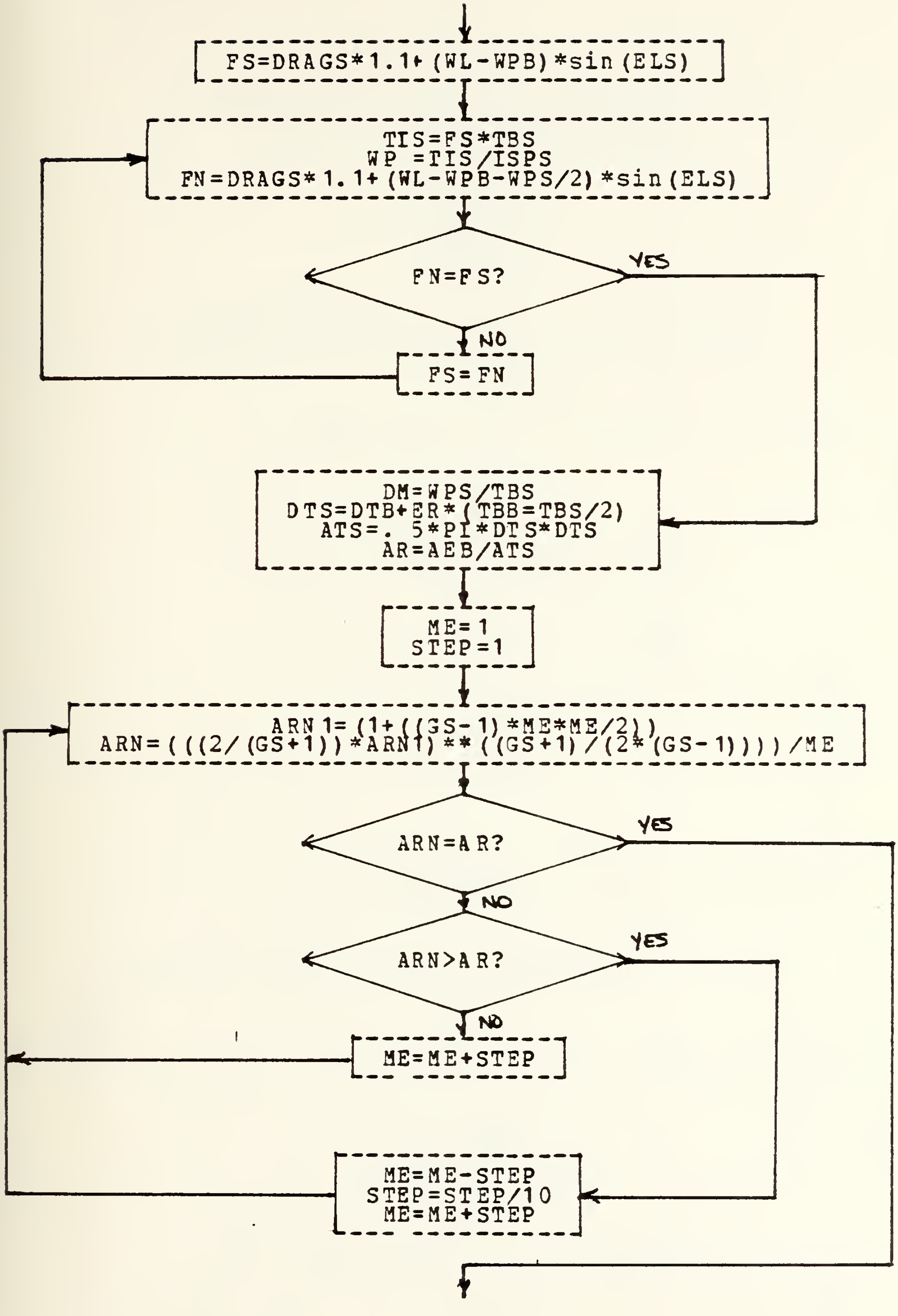
```
   50 FRAGS=(CDEN*5.*PI/FRMLB(1))*(2.*RW*RW*CTH-RW*CTH*CTH)
      FRLEN=(FRMLB(1)/(CTH*CDEN))**.5
      HITS=FRAGS*A
      RETURN
      END
C
C
C
C
      SUBROUTINE SCREEN
      WRITE (6,600)
  600 FORMAT (1X,'CLEAR SCREEN AND ENTER "0"')
      READ (6,16) ISCR
   16 FORMAT (1I1)
      RETURN
      END
```

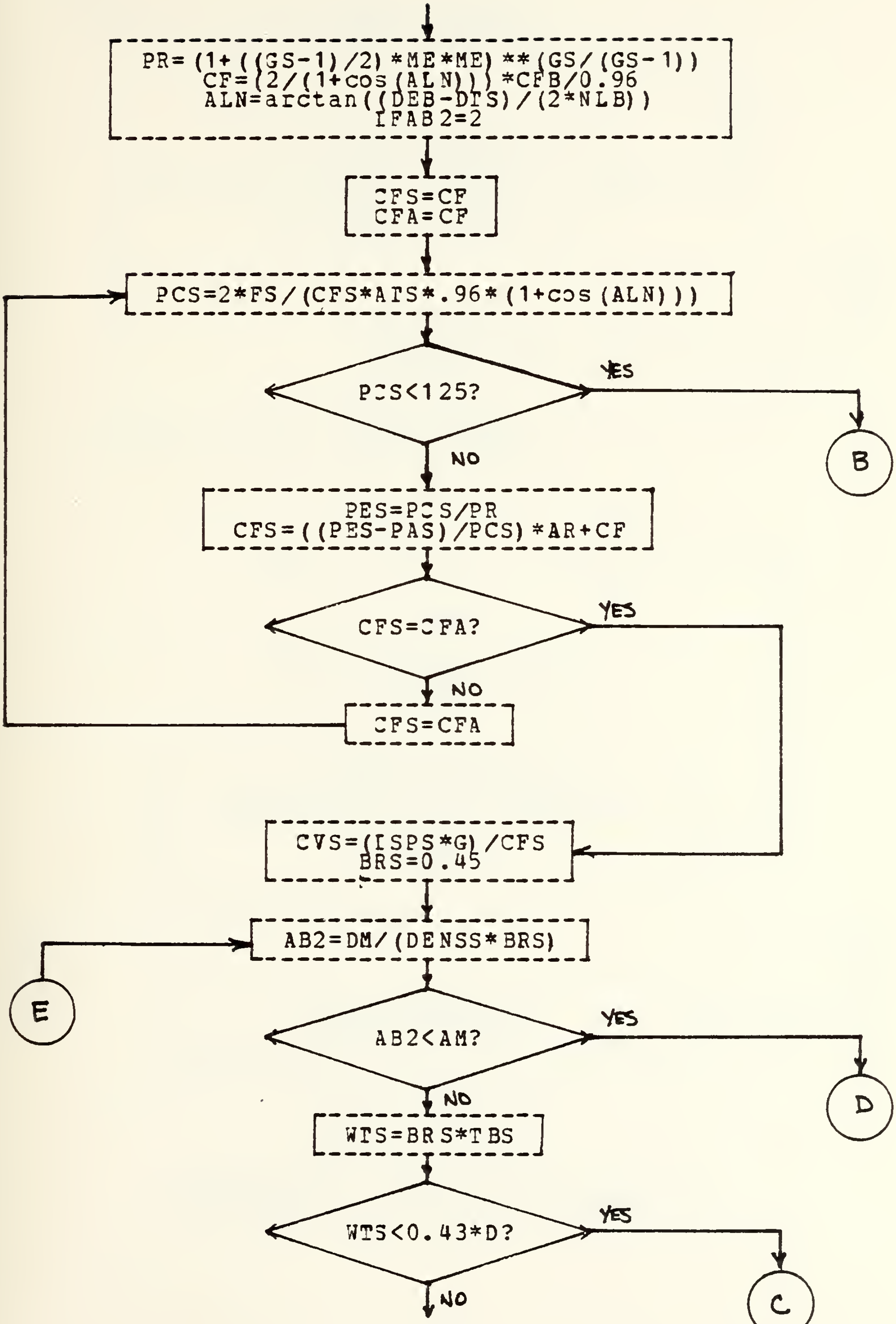
# APPENDIX E. PROPULSION SIZING PROGRAM FLOWCHART

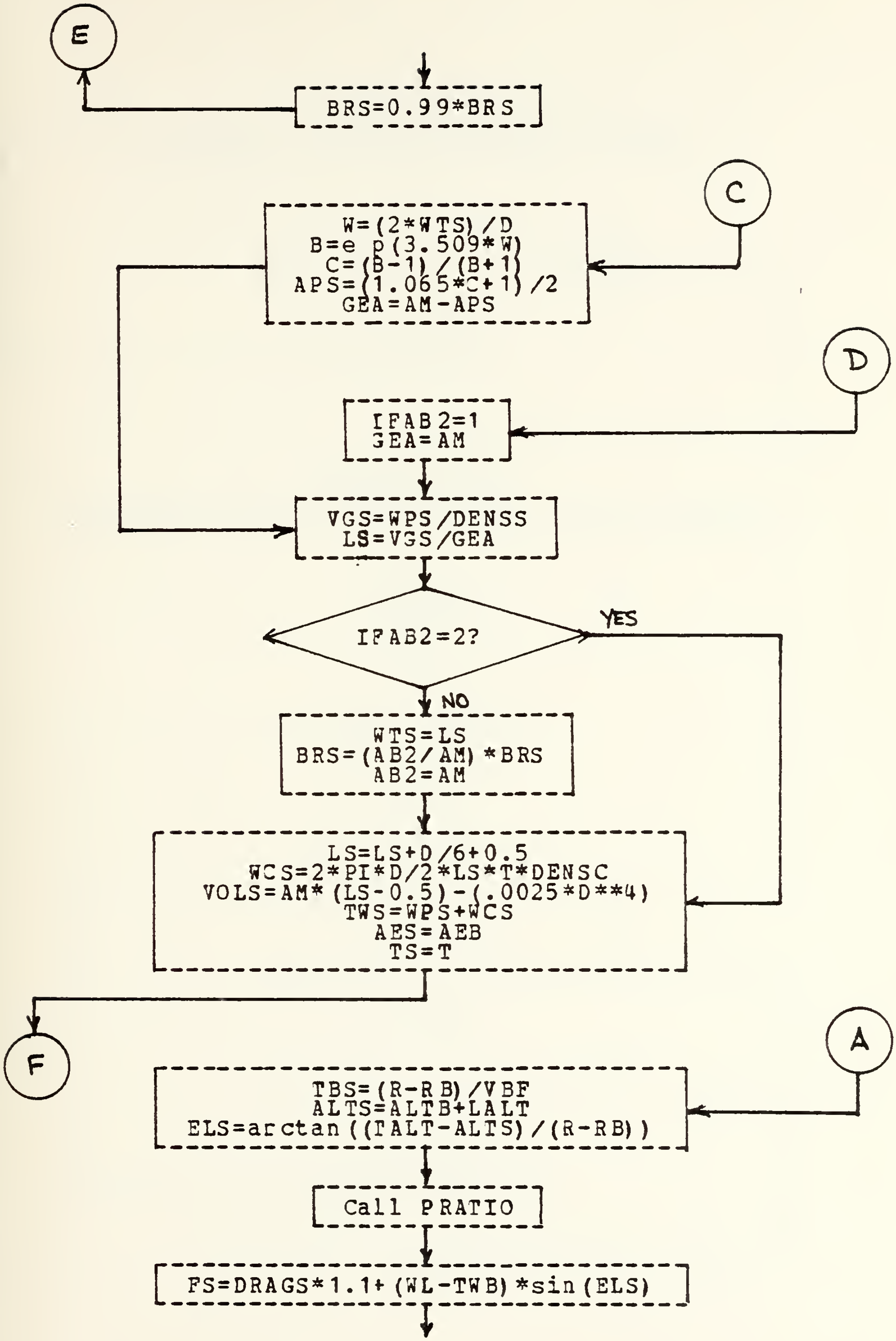

MAIN PROGRAM
Input IMOTOR,LALT,WL,VBI,ELB,A,VBF,
DRAGS,R,TALT,ISPB,DENSB,GB,ISPS,
DENSS,GS,ALN
IMOTOR=1?
YES
NO
Input ALTBN,ER,DB,YIELD,DENSC
Input ALTBN,ER,DB,YIELD,DENSC,
ALTSN,D,YIELDS,DENCSC
Display input parameters
NO
Is input correct?
YES
DV=VBF-VBI
DF=(VBF*VBF)/DRAGS
DRAGB=((VBF+VBI)**2)/(4*DF)
FB=(WL*A)+DRAGB
DM=FB/ISPB
TBB=DV/(A*G)
RB=(VBI+.5*DV)*TBB*cos(ELB)
ALTBN=(VBI+.5*DV)*TBB*sin(ELB)+LALT
Call PRATIO
WPB=TBB*DM

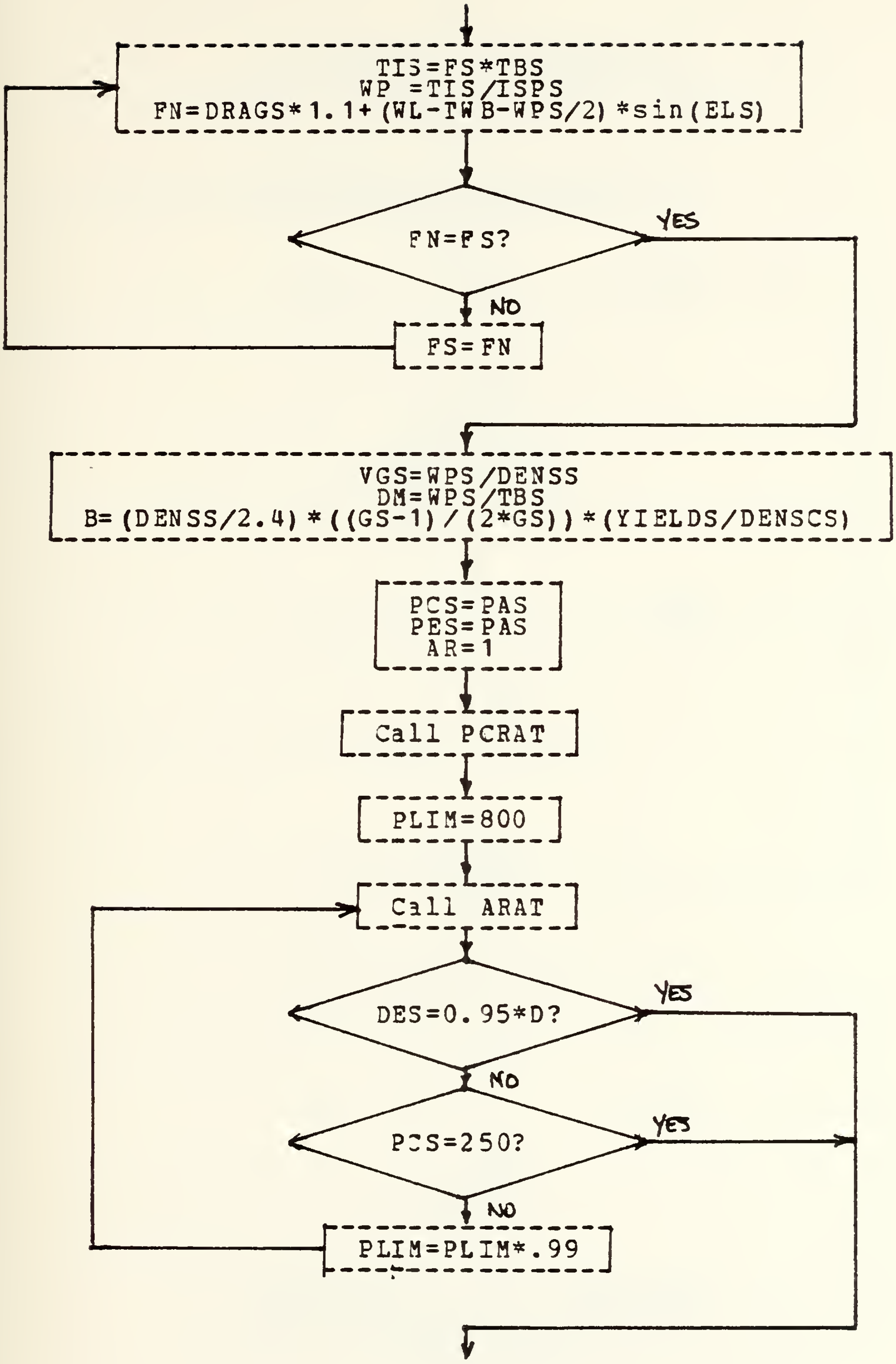

TIB=WPB*ISPB
FB=TIB/TBB
B=(DV/(G*TBB))+sin(ELB)
WN=WL*(1-exp( -WPB/(FB-DRAGB))*B))
WPB=WN?
YES
NO
WPB=WN
DM=WPB/TBB
VGB=WPB/DENSB
'TEP=100
B=(DENSB/2.4)*((GB-1)/(2*GB))*(YIELD/DENSC)
PCB=PAB
PEB=PAB
AR=1
Call PCRAT
PLIM=2000
Call ARAT
Is
IMOTO R=0?
or
DEB>(0.95*DB)?
or
PCB<1000?
YES
NO
PLIM=PLIM*.99

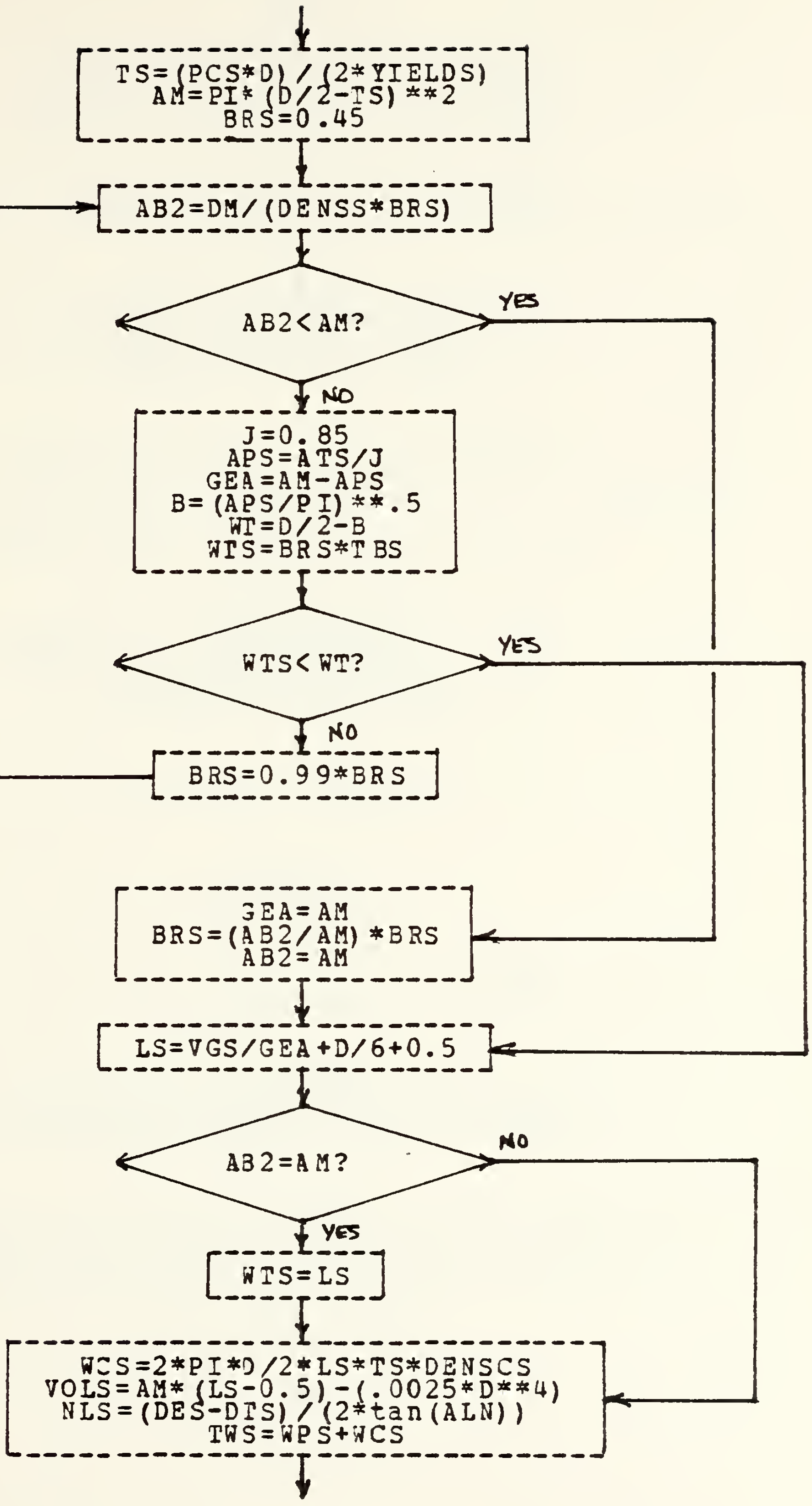

T=(PCB*DB)/(2*YIELD)
J=0.85
APB=ATB/J
AM=PI*(DB/2-T)**2
GEA=AM-APB
BRB=1.25
B=(APB/PI)**.5
WT=(DB/2)-B
ABB=DM/(DENSB*BRB)
WTB=BRB*TBB
WTB<WT?
YES
NO
BRB=.99*BRB
LB=VGB/GEA+DB/6+0.5
WCB=2*PI DB/2*LB*T*DENSC
VOLB=AM*(LB-0.5)-(.0025*DB**4)
NLB=(DEB-DTB)/(2*tan(ALN))
TWB=WPB+WCB
IMOTOR=1?
YES
NO
A
TBS=(R-RB)/VBF
ALTS=ALTB+LALT
ELS=arctan((TALT-ALTS)/(R-RB))
ALTS=VBF*sin(ELS)*TBS*0.5+ALTS
Call PRATIO

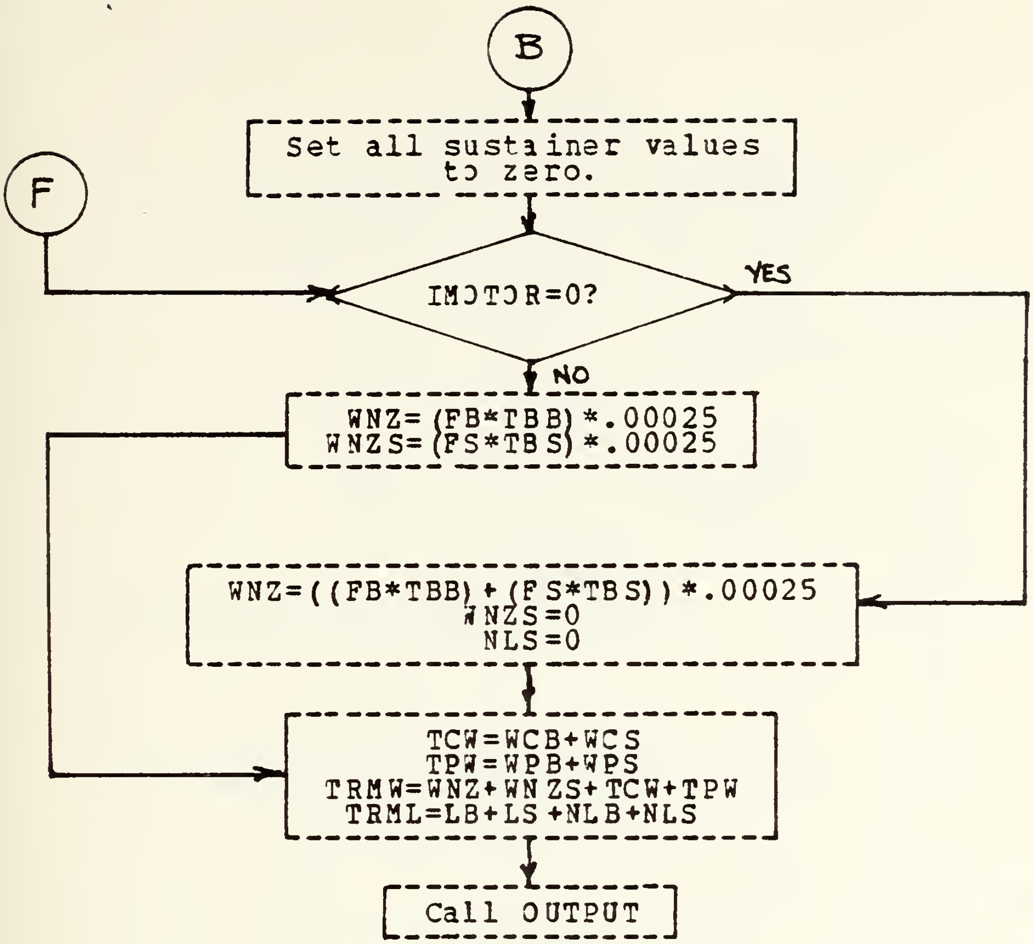

FS=DRAGS*1.1+(WL-WPB)*sin(ELS)
TIS=FS*TBS
WP =TIS/ISPS
FN=DRAGS*1.1+(WL-WPB-WPS/2)*sin(ELS)
FN=FS?
YES
NO
FS=FN
DM=WPS/TBS
DTS=DTB+ER*(TBB=TBS/2)
ATS=.5*PI*DTS*DTS
AR=AEB/ATS
ME=1
STEP=1
ARN1=(1+((GS-1)*ME*ME/2))
ARN=(((2/(GS+1))*ARN1)**((GS+1)/(2*(GS-1))))/ME
ARN=AR?
YES
NO
ARN>AR?
YES
NO
ME=ME+STEP
ME=ME-STEP
STEP=STEP/10
ME=ME+STEP

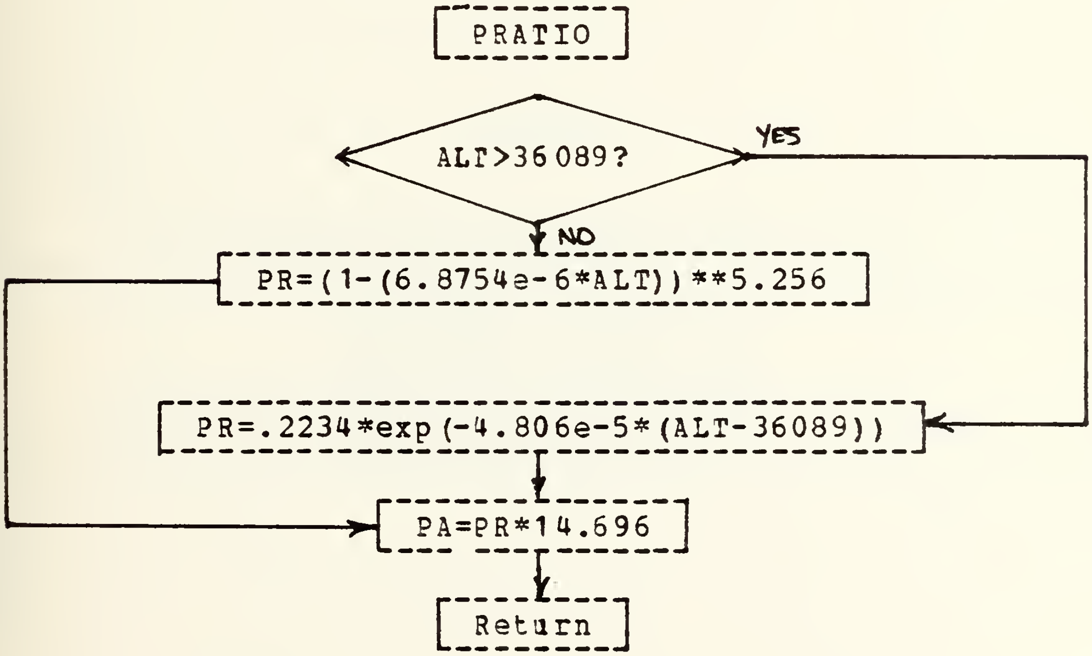

PR=(1+((GS-1)/2)*ME*ME)**(GS/(GS-1))
CF=(2/(1+cos(ALN)))*CFB/0.96
ALN=arctan((DEB-DTS)/(2*NLB))
IFAB2=2
CFS=CF
CFA=CF
PCS=2*FS/(CFS*ATS*.96*(1+cos(ALN)))
PCS<125?
YES
B
NO
PES=PCS/PR
CFS=((PES-PAS)/PCS)*AR+CF
CFS=CFA?
YES
NO
CFS=CFA
CVS=(ISPS*G)/CFS
BRS=0.45
AB2=DM/(DENSS*BRS)
E
AB2<AM?
YES
D
NO
WTS=BRS*TBS
WTS<0.43*D?
YES
C
NO

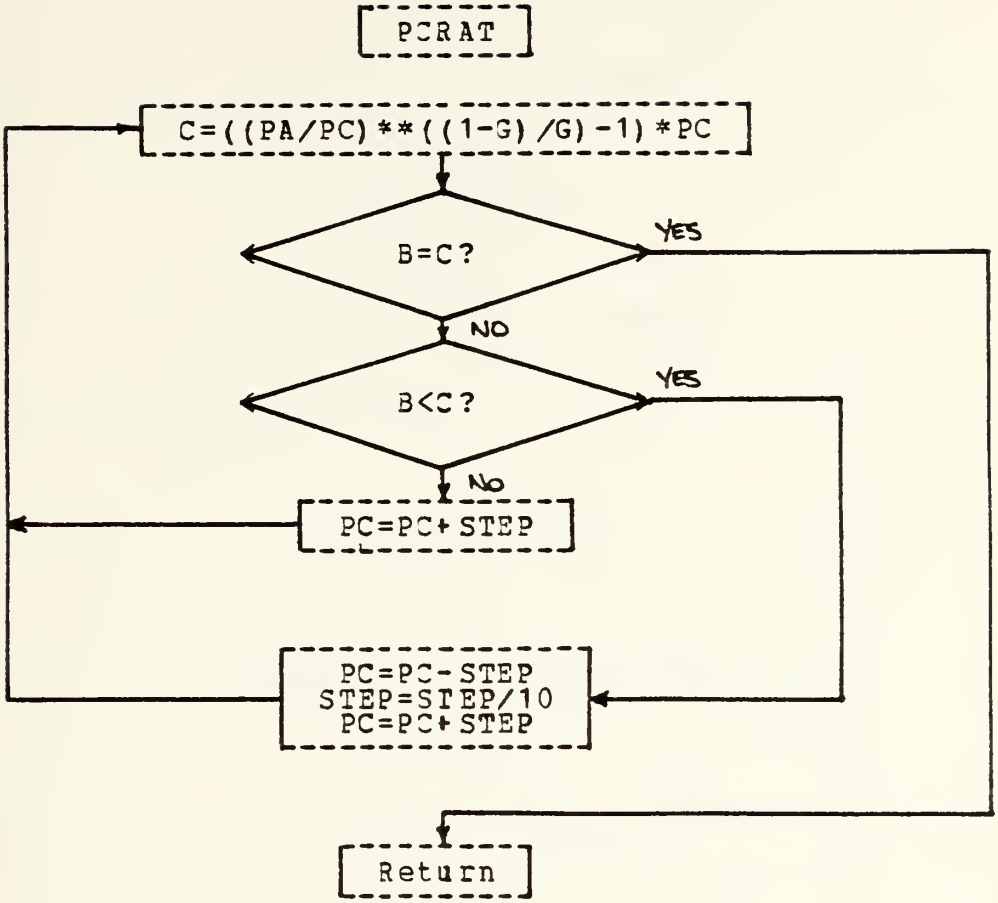

E
BRS=0.99*BRS
C
W=(2*WTS)/D
B=e p(3.509*W)
C=(B-1)/(B+1)
APS=(1.065*C+1)/2
GEA=AM-APS
D
IFAB2=1
GEA=AM
VGS=WPS/DENSS
LS=VGS/GEA
IFAB2=2?
YES
NO
WTS=LS
BRS=(AB2/AM)*BRS
AB2=AM
LS=LS+D/6+0.5
WCS=2*PI*D/2*LS*T*DENSC
VOLS=AM*(LS-0.5)-(.0025*D**4)
TWS=WPS+WCS
AES=AEB
TS=T
F
A
TBS=(R-RB)/VBF
ALTS=ALTB+LALT
ELS=arctan((TALT-ALTS)/(R-RB))
Call PRATIO
FS=DRAGS*1.1+(WL-TWB)*sin(ELS)

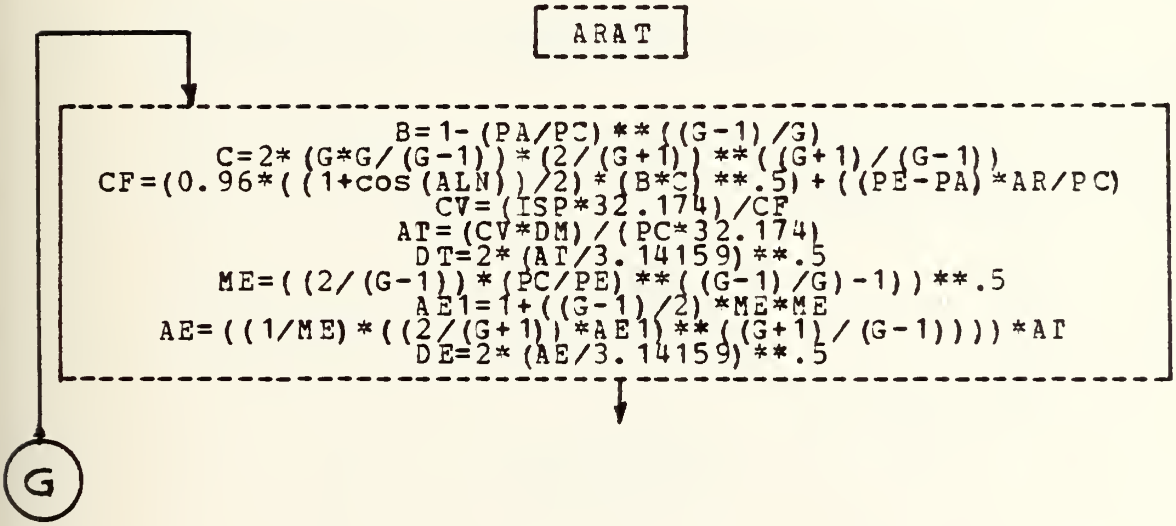

TIS=FS*TBS
WP =TIS/ISPS
FN=DRAGS*1.1+(WL-TWB-WPS/2)*sin(ELS)
FN=FS?
YES
NO
FS=FN
VGS=WPS/DENSS
DM=WPS/TBS
B=(DENSS/2.4)*((GS-1)/(2*GS))*(YIELDS/DENSCS)
PCS=PAS
PES=PAS
AR=1
Call PCRAT
PLIM=800
Call ARAT
DES=0.95*D?
YES
NO
PCS=250?
YES
NO
PLIM=PLIM*.99

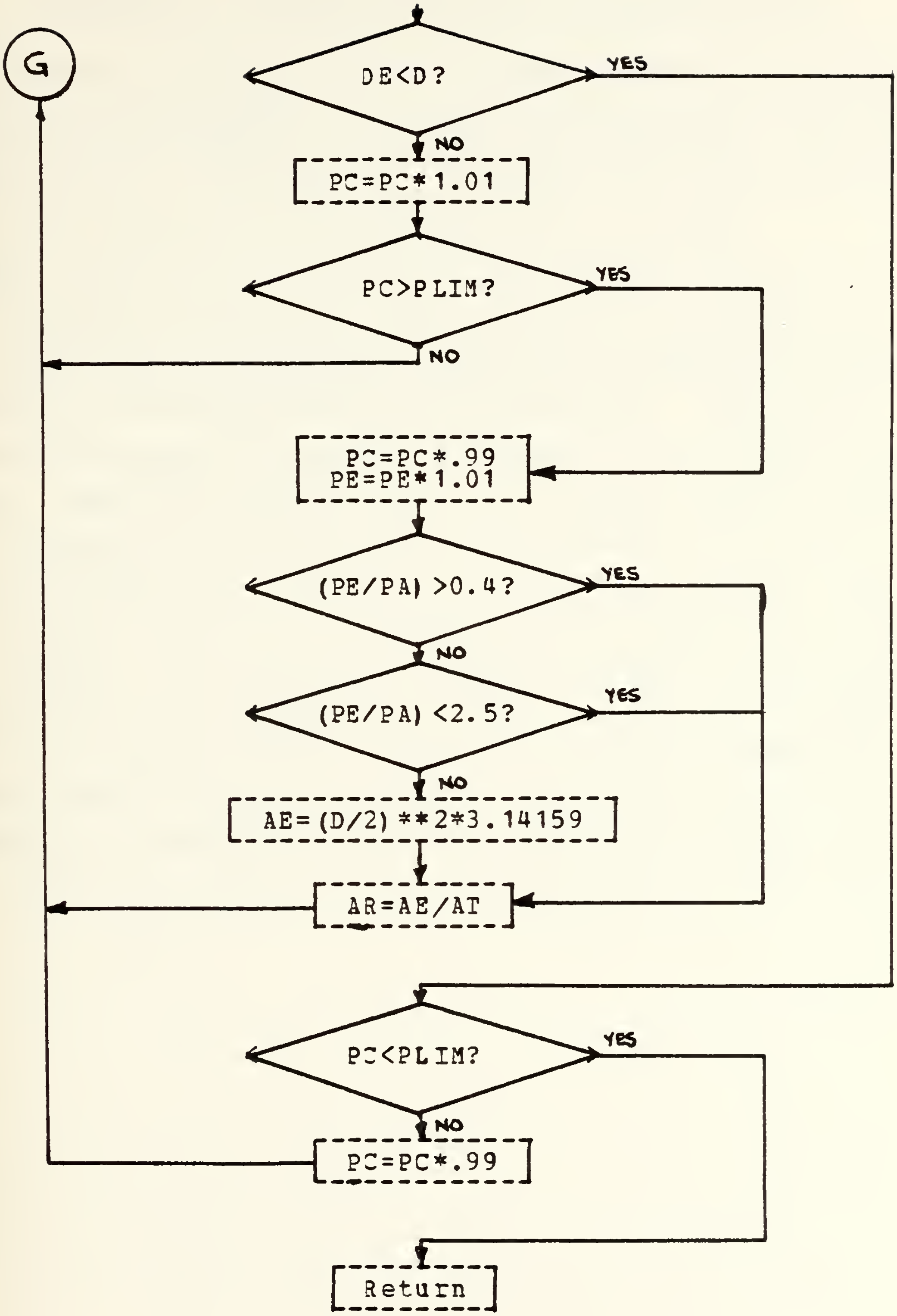

TS=(PCS*D)/(2*YIELDS)
AM=PI*(D/2-TS)**2
BRS=0.45
AB2=DM/(DENSS*BRS)
AB2<AM?
YES
NO
J=0.85
APS=ATS/J
GEA=AM-APS
B=(APS/PI)**.5
WT=D/2-B
WTS=BRS*TBS
WTS<WT?
YES
NO
BRS=0.99*BRS
GEA=AM
BRS=(AB2/AM)*BRS
AB2=AM
LS=VGS/GEA+D/6+0.5
AB2=AM?
NO
YES
WTS=LS
WCS=2*PI*D/2*LS*TS*DENSCS
VOLS=AM*(LS-0.5)-(.0025*D**4)
NLS=(DES-DTS)/(2*tan(ALN))
TWS=WPS+WCS


B
Set all sustainer values to zero.
F
IMOTOR=0?
YES
NO
WNZ=(FB*TBB)*.00025
WNZS=(FS*TBS)*.00025
WNZ=((FB*TBB)+(FS*TBS))*.00025
WNZS=0
NLS=0
TCW=WCB+WCS
TPW=WPB+WPS
TRMW=WNZ+WNZS+TCW+TPW
TRML=LB+LS+NLB+NLS
Call OUTPUT


PRATIO
ALT>36089?
YES
NO
PR=(1-(6.8754e-6*ALT))**5.256
PR=.2234*exp(-4.806e-5*(ALT-36089))
PA=PR*14.696
Return


PCRAT
C=((PA/PC)**((1-G)/G)-1)*PC
B=C?
YES
NO
B<C?
YES
NO
PC=PC+STEP
PC=PC-STEP
STEP=STEP/10
PC=PC+STEP
Return


ARAT
B=1-(PA/PC)**((G-1)/G)
C=2*(G*G/(G-1))*(2/(G+1))**((G+1)/(G-1))
CF=(0.96*((1+cos(ALN))/2)*(B*C)**.5)+((PE-PA)*AR/PC)
CV=(ISP*32.174)/CF
AT=(CV*DM)/(PC*32.174)
DT=2*(AT/3.14159)**.5
ME=((2/(G-1))*(PC/PE)**((G-1)/G)-1))**.5
AE1=1+((G-1)/2)*ME*ME
AE=((1/ME)*((2/(G+1))*AE1)**((G+1)/(G-1)))))*AT
DE=2*(AE/3.14159)**.5
G


G
DE<D?
YES
NO
PC=PC*1.01
PC>PLIM?
YES
NO
PC=PC*.99
PE=PE*1.01
(PE/PA)>0.4?
YES
NO
(PE/PA)<2.5?
YES
NO
AE=(D/2)**2*3.14159
AR=AE/AT
PC<PLIM?
YES
NO
PC=PC*.99
Return

# APPENDIX F. PROPULSION SIZING PROGRAM LISTING

Following this page is the program listing for the Propulsion Sizing Program. It has two segments; the executive routine and the FORTRAN IV computational program. The executive routine establishes the required file definitions and initiates operation of the computational program.

The computational program, LPROP FORTRAN, consists of six subprogram divisions. The MAIN program accepts the input data from the user and performs the guiding calculations for the booster and sustainer motors. Subroutine PRATIO determines the ambient pressures at the design altitudes. Subroutine PCRAT defines the optimum chamber pressure to ambient pressure ratio with respect to the case material properties. Subroutine ARAT solves for the area ratio of the nozzle and tries to size the nozzle to the missile diameter by varying the chamber pressure, characteristic velocity, and thrust coefficient. Subroutine SCREEN is used to prompt the user to clear the terminal screen for proper positioning of the output. And subroutine OUTPUT formats the calculated solutions and provides them to the user and to the printer file, if so directed by the user.

```
FILE: LPROP    EXEC     A   NAVAL POSTGRADUATE SCHOOL

FILEDEF 08 DISK LPROP OUTPUT A0  (RECFM VA BLOCK 133 PERM
&BEGTYPE

YOU WILL HAVE THE OPTION TO OBTAIN A HARDCOPY PRINTOUT OF
AS MANY ALTERNATIVES AS YOU WISH.  THE PROGRAM WILL ASK
YOU IF YOU DESIRE TO SAVE A PARTICULAR RUN, SIMPLY ANSWER
ACCORDINGLY.

&END
LOAD LPROP
START
&BEGTYPE

TO OBTAIN A HARDCOPY PRINTOUT OF THE RESULTS, TYPE "PRINT
LPROP OUTPUT" AND ENTER.  THE OUTPUT WILL BE PRINTED ON
THE VM PRINTER IN ROOM 140 AND WILL BE IDENTIFIED BY YOUR
USER NUMBER AND LABEL NAME.  IT USUALLY REQUIRES SEVERAL
MINUTES TO OBTAIN THE PRINTOUT.

&END
```

```
C     PROPULSION SIZING PROGRAM                                         LPR00040
C     LT. MARTIN D. SULLIVAN, USN      21 MAY 1981                      LPR00050
C     PROGRAM COORDINATOR:  PROFESSOR GERALD LINDSEY, AERO. DEPARTMENT  LPR00060
C                                                                       LPR00070
      REAL PI,G,DV,VBF,VBI,DF,DRAGS,DRAGB,FB,WL,A,DM,ISPB,TBB,WPB       LPR00080
      REAL ABB,DENSB,BRB,WTB,VGB,B,GB,YIELD,DENSC,PCB,PAB,C,AEB1        LPR00090
      REAL ATB,DTB,ME,AEB,DEB,D,T,J,APB,AM,GEA,LB,WCB,VOLB,NLB          LPR00100
      REAL FS,ELS,TIS,ISPS,FN,DTS,ER,ATS,AR,ARN,GS,PR,CF,CFS,ARN1       LPR00110
      REAL ISPS,CVS,AB2,BRS,WTS,W,APS,DENSS,VGS,LS,WCS,VOLS,TWS         LPR00120
      REAL TIB,WN,ELB,STEP,CFB,ALN,CVB,RB,R,TWB,TBS,CFA,PCS,PES,PAS     LPR00130
      REAL LALT,TALT,PEB,ALTB,ALTS,TCW,WNZ,TPW,TRMW,TRML,AES            LPR00140
      REAL YIELDS,DENSCS,TS,WNZS,NLS,PLIM,DB,ALTBN,ALTSN                LPR00150
      INTEGER ICOR,IGO,IFBRB,IFDLMB,IFAB2,IFBRS,IFPCS,IFDLMS,IMOTOR     LPR00160
      INTEGER IFPCB,IFTRMW,IFBSTO,IFTRML                                LPR00170
      COMMON WPB,WCB,TWB,CFB,CVB,FB,TBB,RB,PCB,ABE,WTB,APB,LB,VOLB      LPR00180
      COMMON ATB,BRB,NLB,AEB,WNZ,TPW,TCW,TRMW,TRML,T                    LPR00190
      COMMON WPS,WCS,TWS,CFS,CVS,FS,TBS,PCS,AB2,WTS,APS,LS,VOLS,ATS,BRS LPR00200
      COMMON VBF,VBI,YIELD,DENSC,ALN,ER,D,R,WL,A,ELB,ISPB               LPR00210
      COMMON DENSB,GB,LALT,DRAGS,TALT,ISPS,GS,DENSS,DB                  LPR00220
      COMMON YIELDS,DENSCS,TS,WNZS,NLS,AES,ALTBN,ALTSN                  LPR00230
      COMMON IFBRB,IFDLMB,IFAB2,IFBRS,IFPCB,IFTRMW,IFBSTO,IFTRML,IFPCS  LPR00240
      COMMON IFDLMS,IMOTOR                                              LPR00250
      DETORA(X)=(X/360)*2*3.1415926535                                  LPR00260
      RATODE(X)=(X/(2*3.1415926535))*360                                LPR00270
  997 ICOR=0                                                            LPR00280
 1100 FORMAT (F15.4)                                                    LPR00290
 1110 FORMAT (I2)                                                       LPR00300
 1120 FORMAT (I1)                                                       LPR00310
      WRITE (6,1300)                                                    LPR00320
 1300 FORMAT (1X,'INPUT "0" FOR INTEGRAL MOTORS (COMMON NOZZLE) OR "1" FLPR00330
     +OR STAGED'/,1X,'MOTORS (SEPARATE NOZZLES).')                      LPR00340
      READ (5,1120) IMOTOR                                              LPR00350
    1 WRITE (6,1310)                                                    LPR00360
 1310 FORMAT (1X,'ENTER THE FOLLOWING DATA AS DECIMAL NUMBERS ONLY ')   LPR00370
 6001 WRITE (6,1001)                                                    LPR00380
 1001 FORMAT (1X,'INPUT LAUNCH ALTITUDE (FEET)')                        LPR00390
      READ (5,1100) LALT                                                LPR00400
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00410
 6002 WRITE (6,1002)                                                    LPR00420
 1002 FORMAT (1X,'INPUT LAUNCH WEIGHT (POUNDS)')                        LPR00430
      READ (5,1100) WL                                                  LPR00440
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00450
 6003 WRITE (6,1003)                                                    LPR00460
 1003 FORMAT (1X,'INPUT LAUNCH VELOCITY (FT/SEC)')                      LPR00470
      READ (5,1100) VBI                                                 LPR00480
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00490
 6004 WRITE (6,1004)                                                    LPR00500
 1004 FORMAT (1X,'INPUT LAUNCH ANGLE (DEGREES)')                        LPR00510
```

```
      READ (5,1100) ELB                                                 LPR00520
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00530
 6005 WRITE (6,1005)                                                    LPR00540
 1005 FORMAT (1X,'INPUT AVERAGE ACCELERATION DURING BOOST (G"S)')       LPR00550
      READ (5,1100) A                                                   LPR00560
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00570
 6006 WRITE (6,1006)                                                    LPR00580
 1006 FORMAT (1X,'INPUT CRUISE VELOCITY (FT/SEC)')                      LPR00590
      READ (5,1100) VBF                                                 LPR00600
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00610
 6007 WRITE (6,1007)                                                    LPR00620
 1007 FORMAT (1X,'INPUT DRAG ON MISSILE AT CRUISE VELOCITY (POUNDS)')   LPR00630
      READ (5,1100) DRAGS                                               LPR00640
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00650
 6008 WRITE (6,1008)                                                    LPR00660
 1008 FORMAT (1X,'INPUT MAXIMUM RANGE (NAUTICAL MILES)')                LPR00670
      READ (5,1100) R                                                   LPR00680
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00690
 6009 WRITE (6,1009)                                                    LPR00700
 1009 FORMAT (1X,'INPUT FINAL (TARGET) ALTITUDE (FEET)')                LPR00710
      READ (5,1100) TALT                                                LPR00720
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00730
 6010 WRITE (6,1010)                                                    LPR00740
 1010 FORMAT (1X,'INPUT BOOSTER PROPELLANT SPECIFIC IMPULSE (SECONDS)') LPR00750
      READ (5,1100) ISPB                                                LPR00760
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00770
 6011 WRITE (6,1011)                                                    LPR00780
 1011 FORMAT (1X,'INPUT BOOSTER PROPELLANT DENSITY (LBS/CU.IN)')        LPR00790
      READ (5,1100) DENSB                                               LPR00800
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00810
 6012 WRITE (6,1012)                                                    LPR00820
 1012 FORMAT (1X,'INPUT BOOSTER EXHAUST SPECIFIC HEAT RATIO')           LPR00830
      READ (5,1100) GB                                                  LPR00840
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00850
 6013 WRITE (6,1013)                                                    LPR00860
 1013 FORMAT (1X,'INPUT SUSTAINER PROPELLANT SPECIFIC IMPULSE (SEC)')   LPR00870
      READ (5,1100) ISPS                                                LPR00880
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00890
 6014 WRITE (6,1014)                                                    LPR00900
 1014 FORMAT (1X,'INPUT SUSTAINER PROPELLANT DENSITY (LBS/CU.IN)')      LPR00910
      READ (5,1100) DENSS                                               LPR00920
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00930
 6015 WRITE (6,1015)                                                    LPR00940
 1015 FORMAT (1X,'INPUT SUSTAINER EXHAUST SPECIFIC HEAT RATIO')         LPR00950
      READ (5,1100) GS                                                  LPR00960
      IF (ICOR.EQ.1) GO TO 1260                                         LPR00970
 6016 WRITE (6,1016)                                                    LPR00980
 1016 FORMAT (1X,'INPUT NOZZLE HALF ANGLE (DEGREES)')                   LPR00990
```

```
      READ (5,1100) ALN
      IF (ICOR.EQ.1) GJ TO 1260
      IF (IMOTOR.EQ.1) GO TO 90
 6017 WRITE (6,1017)
 1017 FORMAT (1X,'INPUT NOZZLE DESIGN ALTITUDE (FEET)')
      READ (5,1100) ALTBN
      IF (ICOR.EQ.1) GO TO 1260
 6018 WRITE (6,1018)
 1018 FORMAT (1X,'INPUT NOZZLE EROSION RATE (IN/SEC)')
      READ (5,1100) ER
      IF (ICOR.EQ.1) GO TO 1260
 6019 WRITE (6,1019)
 1019 FORMAT (1X,'INPUT MISSILE DIAMETER (INCHES)')
      READ (5,1100) DB
      D=DB
      IF (ICOR.EQ.1) GO TO 1260
 6020 WRITE (6,1020)
 1020 FORMAT (1X,'INPUT YIELD STRENGTH OF CASE MATERIAL (PSI)')
      READ (5,1100) YIELD
      YIELDS=YIELD
      IF (ICOR.EQ.1) GO TO 1260
 6021 WRITE (6,1021)
 1021 FORMAT (1X,'INPUT DENSITY OF THE CASE MATERIAL (LB/CU.IN)')
      READ (5,1100) DENSC
      DENSCS=DENSC
      IF (ICOR.EQ.1) GO TO 1260
      GO TO 1201
   90 CONTINUE
 6022 WRITE (6,1022)
 1022 FORMAT (1X,'INPUT BOOSTER NOZZLE CESIGN ALTITUDE (FEET)')
      READ (5,1100) ALTBN
      IF (ICOR.EQ.1) GO TO 1260
 6023 WRITE (6,1023)
 1023 FORMAT (1X,'INPUT BOOSTER DIAMETER (INCHES)')
      READ (5,1100) DB
      IF (ICOR.EQ.1) GO TO 1260
 6024 WRITE (6,1024)
 1024 FORMAT (1X,'INPUT YIELD STRENGTH OF BOOSTER CASE MATERIAL (PSI)')
      READ (5,1100) YIELD
      IF (ICOR.EQ.1) GO TO 1260
 6025 WRITE (6,1025)
 1025 FORMAT (1X,'INPUT DENSITY OF BOOSTER CASE MATERIAL (LBS/CU.IN)')
      READ (5,1100) DENSC
      IF (ICOR.EQ.1) GO TO 1260
 6026 WRITE (6,1026)
 1026 FORMAT (1X,'INPUT SUSTAINER NOZZLE DESIGN ALTITUDE (FEET)')
      READ (5,1100) ALTSN
      IF (ICOR.EQ.1) GO TO 1260
```

```
6027 WRITE (6,1027)                                                    LPRO1480
1027 FORMAT (1X,'INPUT SUSTAINER DIAMETER (INCHES)')                   LPRO1490
     READ (5,1100) D                                                   LPRO1500
     IF (ICOR.EQ.1) GO TO 1260                                         LPRO1510
6028 WRITE (6,1028)                                                    LPRO1520
1028 FORMAT(1X,'INPUT YIELD STRENGTH OF SUSTAINER CASE MATERIAL (PSI)')LPRO1530
     READ (5,1100) YIELDS                                              LPRO1540
     IF (ICOR.EQ.1) GO TO 1260                                         LPRO1550
6029 WRITE (6,1029)                                                    LPRO1560
1029 FORMAT (1X,'INPUT DENSITY OF SUSTAINER CASE MATERIAL (LBS/CU.IN)')LPRO1570
     READ (5,1100) DENSCS                                              LPRO1580
     IF (ICOR.EQ.1) GO TO 1260                                         LPRO1590
1201 CONTINUE                                                          LPRO1600
     CALL SCREEN                                                       LPRO1610
     WRITE (6,1202)                                                    LPRO1620
1202 FORMAT (/1X,'REVIEW THE FOLLOWING LIST OF INPUT PARAMETERS AND RECLPRO1630
    +ORD THE NUMBERS'/,1X,'OF THOSE TO BE CHANGED.'/)                  LPRO1640
     ICOR=1                                                            LPRO1650
     WRITE (6,1210) LALT,WL,VBI,ELB,A,VBF,DRAGS,R,TALT,ISPB,DENSB,GB   LPRO1660
1210 FORMAT (1X,'SUMMARY OF INPUT PARAMETERS==========================',LPRO1670
    +/5X,'01) LAUNCH ALTITUDE',T45,F12.1,' FEET',                      LPRO1680
    +/5X,'02) LAUNCH WEIGHT',T45,F12.2,' POUNDS',                      LPRO1690
    +/5X,'03) LAUNCH VELOCITY',T45,F12.1,' FT/SEC',                    LPRO1700
    +/5X,'04) LAUNCH ANGLE',T45,F12.1,' DEGREES',                      LPRO1710
    +/5X,'05) AVERAGE ACCELERATION',T45,F12.2,' G"S',                  LPRO1720
    +/5X,'06) CRUISE VELOCITY',T45,F12.1,' FT/SEC',                    LPRO1730
    +/5X,'07) DRAG AT CRUISE VELOCITY',T45,F12.1,' POUNDS',            LPRO1740
    +/5X,'08) MAXIMUM RANGE',T45,F12.0,' MILES',                       LPRO1750
    +/5X,'09) FINAL (TARGET) ALTITUDE',T45,F12.1,' FEET',              LPRO1760
    +/5X,'10) BOOSTER PROPELLANT SPECIFIC IMPULSE',T45,F12.1,' SEC',   LPRO1770
    +/5X,'11) BOOSTER PROPELLANT DENSITY',T45,F12.4,' LBS/CU.IN',      LPRO1780
    +/5X,'12) BOOSTER EXHAUST SPECIFIC HEAT RATIO',T50,F7.5)           LPRO1790
     WRITE (6,1220) ISPS,DENSS,GS,ALN                                  LPRO1800
1220 FORMAT (5X,'13) SUSTAINER PROPELLANT SPECIFIC IMPULSE',T50,F7.1,  LPRO1810
    +' SEC',                                                           LPRO1820
    +/5X,'14) SUSTAINER PROPELLANT DENSITY',T45,F12.4,' LBS/CU.IN',    LPRO1830
    +/5X,'15) SUSTAINER EXHAUST SPECIFIC HEAT RATIO',T50,F7.5,         LPRO1840
    +/5X,'16) NOZZLE HALF ANGLE',T45,F12.2,' DEGREES')                 LPRO1850
     IF (IMOTOR.EQ.1) GO TO 1240                                       LPRO1860
     WRITE (6,1230) ALTBN,ER,DB,YIELD,DENSC                            LPRO1870
1230 FORMAT (5X,'17) NOZZLE DESIGN ALTITUDE',T45,F12.1,' FEET',        LPRO1880
    +/5X,'18) NOZZLE EROSION RATE',T45,F12.5,' IN/SEC',                LPRO1890
    +/5X,'19) MISSILE DIAMETER',T45,F12.1,' INCHES',                   LPRO1900
    +/5X,'20) YIELD STRENGTH OF CASE MATERIAL',T45,F12.1,' PSI',       LPRO1910
    +/5X,'21) DENSITY OF CASE MATERIAL',T45,F12.4,' LBS/CU.IN')        LPRO1920
     GO TO 1250                                                        LPRO1930
1240 WRITE (6,1245) ALTBN,DB,YIELD,DENSC,ALTSN,D,YIELDS,DENSCS         LPRO1940
1245 FORMAT (5X,'17) BOOSTER DESIGN ALTITUDE',T45,F12.1,' FEET',       LPRO1950
```

```
     +/5X,'18) BOOSTER DIAMETER',T45,F12.2,' INCHES',
     +/5X,'19) YIELD STRENGTH OF BOOSTER CASE',T45,F12.1,' PSI',
     +/5X,'20) DENSITY OF BOOSTER CASE MATERIAL',T45,F12.4,' LBS/CU.IN',
     +/5X,'21) SUSTAINER DESIGN ALTITUDE',T45,F12.1,' FEET',
     +/5X,'22) SUSTAINER DIAMETER',T45,F12.2,' INCHES',
     +/5X,'23) YIELD STRENGTH OF SUSTAINER CASE',T45,F12.1,' PSI',
     +/5X,'24) DENSITY OF SUSTAINER CASE MATERIAL',T45,F12.4,' LBS/CU.IN
     +')
 1250 CONTINUE
      WRITE (6,1254)
 1254 FORMAT (/1X,'HOW MANY INPUT PARAMETERS DO YOU WISH TO CHANGE? (TWO
     + DIGIT INTEGER, PLEASE)')
      READ (5,1110) N
      IF (N.EQ.0) GO TO 1301
      DO 1260 I=1,N
 1255    WRITE (6,1256)
 1256    FORMAT (1X,'INPUT TWO DIGIT ITEM NUMBER OF PARAMETER TO BE CHAN
     +GED.')
         READ (5,1110) IGO
         IF ((IGO.GE.1).AND.(IGO.LE.24)) GO TO 1258
         WRITE (6,1257) IGO
 1257    FORMAT(/1X,'WRONG   ',I2,' IS NOT A VALID CHOICE.  TRY AGAIN.')
         GO TO 1255
 1258    IF ((IMOTOR.EQ.1).AND.(IGO.GT.16)) IGO=IGO+5
 1261    GO TO (6001,6002,6003,6004,6005,6006,6007,6008,6009,6010,6011,
     +6012,6013,6014,6015,6016,6017,6018,6019,6020,6021,6022,6023,6024,
     +6025,6026,6027,6028,6029),IGO
 1260 CONTINUE
      GO TO 1201
 1301 CONTINUE
      CALL SCREEN
      PI=3.1415927
      G=32.174
      ALN=DETORA(ALN)
      ELB=DETORA(ELB)
      R=R*6080.
C
C=====BOOSTER MOTOR CALCULATIONS=======================================
C
      DV=VBF-VBI
      DF=(VBF*VBF)/DRAGS
      DRAGB=(VBF+VBI)**2./(4.*DF)
      FB=(WL*A)+DRAGB
      DM=FB/ISPB
      TBB=DV/(A*G)
      RB=(VBI+0.5*DV)*TBB*COS(ELB)
      ALTB=(VBI+0.5*DV)*TBB*SIN(ELB)+LALT
      CALL PRATIO (ALTBN,PAB)
```

```
      WPB=TBB*DM                                                        LPR02440
C                                                                       LPR02450
  100 TIB=WPB*ISPB                                                      LPR02460
      FB=TIB/TBB                                                        LPR02470
      B=DV/(G*TBB)+SIN(ELB)                                             LPR02480
      WN=WL*(1.-EXP((-WPB/(FB-DRAGB))*B))                               LPR02490
      IF (ABS(WPB-WN).LT.0.01) GO TO 110                                LPR02500
      WPB=WN                                                            LPR02510
      GO TO 100                                                         LPR02520
C                                                                       LPR02530
  110 CONTINUE                                                          LPR02540
      WPB=WN                                                            LPR02550
      DM=WPB/TBB                                                        LPR02560
C                                                                       LPR02570
  113 CONTINUE                                                          LPR02580
      VGB=WPB/DENSB                                                     LPR02590
      STEP=100.                                                         LPR02600
      B=(DENSB/2.4)*((GB-1.)/(2.*GB))*(YIELD/DENSC)                     LPR02610
      PCB=PAB                                                           LPR02620
      PEB=PAB                                                           LPR02630
      AR=1.                                                             LPR02640
      IFDLMB=0                                                          LPR02650
      CALL PCRAT (PAB,PCB,GB,B,STEP)                                    LPR02660
      PLIM=2000.                                                        LPR02670
  140 CALL ARAT (PAB,PCB,GB,PEB,ISPB,DB,CFB,CVB,ATB,DTB,AEB,DEB,IFDLMB, LPR02680
     +IFPCB,AR,ALN,DM,PLIM,IMOTOR)                                      LPR02690
      IF ((IMOTOR.EQ.0).OR.(DEB.GE.(0.95*DB)).OR.(PCB.LT.1000))GO TO 150LPR02700
      PLIM=PLIM*.99                                                     LPR02710
      GO TO 140                                                         LPR02720
C                                                                       LPR02730
  150 CONTINUE                                                          LPR02740
      T=(PCB*DB)/(2.*YIELD)                                             LPR02750
      J=0.85                                                            LPR02760
  160 APB=ATB/J                                                         LPR02770
      AM=PI*(DB/2.-T)**2.                                               LPR02780
      GEA=AM-APB                                                        LPR02790
      IFBRB=0                                                           LPR02800
      BRB=1.25                                                          LPR02810
      B=(APB/PI)**0.5                                                   LPR02820
      C=DB/2.-B                                                         LPR02830
C                                                                       LPR02840
  165 ABB=DM/(DENSB*BRB)                                                LPR02850
      WTB=BRB*TBB                                                       LPR02860
      IF (WTB.LT.C) GO TO 170                                           LPR02870
      BRB=0.99*BRB                                                      LPR02880
      IFBRB=1                                                           LPR02890
      GO TO 165                                                         LPR02900
C                                                                       LPR02910
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  170 LB=VGB/GEA                                                         LPR02920
      LB=LB+DB/6.+0.5                                                    LPR02930
      WCB=2.*PI*DB/2.*LB*T*DENSC                                         LPR02940
      VOLB=AM*(LB-0.5)-(.0025*DB**4.)                                    LPR02950
      NLB=(DEB-DTB)/(2*TAN(ALN))                                         LPR02960
      TWB=WPB+WCB                                                        LPR02970
               WRITE (6,9000)                                            LPR02980
 9000          FORMAT (1X,'MADE IT THIS FAR.')                           LPR02990
      IFBSTO=1                                                           LPR03000
      IF (RB.GT.R) GO TO 999                                             LPR03010
      IFBSTO=0                                                           LPR03020
      IF (IMOTOR.EQ.1) GO TO 300                                         LPR03030
C                                                                        LPR03040
C=====SUSTAINER MOTOR CALCULATIONS (COMMON NOZZLE)=======================LPR03050
C                                                                        LPR03060
  200 TBS=(R-RB)/VBF                                                     LPR03070
      ALTS=ALTB+LALT                                                     LPR03080
      ELS=ATAN((TALT-ALTS)/(R-RB))                                       LPR03090
      ALTS=VBF*SIN(ELS)*TBS*0.5+ALTS                                     LPR03100
      CALL PRATIO (ALTSN,PAS)                                            LPR03110
      FS=DRAGS*1.1+(WL-WPB)*SIN(ELS)                                     LPR03120
C                                                                        LPR03130
  201 TIS=FS*TBS                                                         LPR03140
      WPS=TIS/ISPS                                                       LPR03150
      FN=DRAGS*1.1+(WL-WPB-WPS/2)*SIN(ELS)                               LPR03160
      IF (ABS(FN-FS).LT.0.01) GO TO 210                                  LPR03170
      FS=FN                                                              LPR03180
      GO TO 201                                                          LPR03190
C                                                                        LPR03200
  210 CONTINUE                                                           LPR03210
      FS=FN                                                              LPR03220
      DM=WPS/TBS                                                         LPR03230
      DTS=DTB+ER*(TBB+TBS*0.5)                                           LPR03240
      ATS=.25*PI*DTS*DTS                                                 LPR03250
      AR=AEB/ATS                                                         LPR03260
      ME=1.                                                              LPR03270
      STEP=1.                                                            LPR03280
C                                                                        LPR03290
  220 ARN1=(1.+((GS-1.)*ME*ME/2.))                                       LPR03300
      ARN=(((2./(GS+1.))*ARN1)**((GS+1.)/(2.*(GS-1.))))/ME               LPR03310
      IF (ABS(ARN-AR).LT.0.001) GO TO 240                                LPR03320
      IF (ARN.GT.AR) GO TO 230                                           LPR03330
      ME=ME+STEP                                                         LPR03340
      GO TO 220                                                          LPR03350
  230 CONTINUE                                                           LPR03360
      ME=ME-STEP                                                         LPR03370
      STEP=STEP/10.                                                      LPR03380
      ME=ME+STEP                                                         LPR03390
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      GO TO 220                                                         LPR03400
C                                                                       LPR03410
  240 CONTINUE                                                          LPR03420
      PR=(1.+((GS-1.)/2.)*ME*ME)**(GS/(GS-1.))                          LPR03430
      CF=(2/(1.+COS(ALN)))*CFB/0.96                                     LPR03440
      ALN=ATAN((DEB-DTS)/(2.*NLB))                                      LPR03450
      CFS=CF                                                            LPR03460
      CFA=CF                                                            LPR03470
      IFPCS=0                                                           LPR03480
      IFAB2=2                                                           LPR03490
      IFBRS=0                                                           LPR03500
C                                                                       LPR03510
  250 PCS=2.*FS/(CFS*ATS*0.96*(1.+COS(ALN)))                            LPR03520
      IF (PCS.GT.125.) GO TO 251                                        LPR03530
      IFAB2=0                                                           LPR03540
      IFBSTO=1                                                          LPR03550
      IFPCS=2                                                           LPR03560
      GO TO 999                                                         LPR03570
  251 PES=PCS/PR                                                        LPR03580
      CFS=((PES-PAS)/PCS)*AR+CF                                         LPR03590
      IF (ABS(CFS-CFA).LT.0.001) GO TO 260                              LPR03600
      CFA=CFS                                                           LPR03610
      GO TO 250                                                         LPR03620
C                                                                       LPR03630
  260 CONTINUE                                                          LPR03640
      CVS=(ISPS*G)/CFS                                                  LPR03650
      BRS=0.45                                                          LPR03660
C                                                                       LPR03670
  270 AB2=DM/(DENSS*BRS)                                                LPR03680
      IF (AB2.LT.AM) GO TO 280                                          LPR03690
      WTS=BRS*TBS                                                       LPR03700
      IF (WTS.LT.(0.43*D)) GO TO 275                                    LPR03710
      BRS=0.99*BRS                                                      LPR03720
      IFBRS=1                                                           LPR03730
      GO TO 270                                                         LPR03740
C                                                                       LPR03750
  275 W=(2.*WTS)/D                                                      LPR03760
      B=EXP(3.509*W)                                                    LPR03770
      C=(B-1.)/(B+1.)                                                   LPR03780
      APS=(1.065*C+1.)/2.                                               LPR03790
      GEA=AM-APS                                                        LPR03800
      GO TO 285                                                         LPR03810
  280 IFAB2=1                                                           LPR03820
      GEA=AM                                                            LPR03830
  285 VGS=WPS/DENSS                                                     LPR03840
      LS=VGS/GEA                                                        LPR03850
      IF (IFAB2.EQ.2) GO TO 290                                         LPR03860
      WTS=LS                                                            LPR03870
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      BRS=(AB2/AM)*BRS                                                  LPR03880
      AB2=AM                                                            LPR03890
      IFBRS=1                                                           LPR03900
C                                                                       LPR03910
  290 CONTINUE                                                          LPR03920
      LS=LS+D/6.+.5                                                     LPR03930
      WCS=2*PI*D/2.*LS*T*DENSC                                          LPR03940
      VOLS=AM*(LS-.5)-(.0025*D**4.)                                     LPR03950
      TWS=WPS+WCS                                                       LPR03960
      AES=10000000000000000000.                                         LPR03970
      ATS=10000000000000000000.                                         LPR03980
      TS=T                                                              LPR03990
      GO TO 998                                                         LPR04000
C                                                                       LPR04010
C=====SUSTAINER MOTOR CALCULATIONS (STAGED MOTORS)======================LPR04020
C                                                                       LPR04030
  300 TBS=(R-RB)/VBF                                                    LPR04040
      ALTS=ALTB+LALT                                                    LPR04050
      ELS=ATAN((TALT-ALTS)/(R-RB))                                      LPR04060
      CALL PRATIO (ALTSN,PAS)                                           LPR04070
      FS=DRAGS*1.1+(WL-TWB)*SIN(ELS)                                    LPR04080
C                                                                       LPR04090
  305 TIS=FS*TBS                                                        LPR04100
      WPS=TIS/ISPS                                                      LPR04110
      FN=DRAGS*1.1+(WL-TWB-WPS/2.)*SIN(ELS)                             LPR04120
      IF (ABS(FN-FS).LT.0.01) GO TO 310                                 LPR04130
      FS=FN                                                             LPR04140
      GO TO 305                                                         LPR04150
C                                                                       LPR04160
  310 CONTINUE                                                          LPR04170
      VGS=WPS/DENSS                                                     LPR04180
      DM=WPS/TBS                                                        LPR04190
      STEP=100.                                                         LPR04200
      B=(DENSS/2.4)*((GS-1.)/(2.*GS))*(YIELDS/DENSCS)                   LPR04210
      PCS=PAS                                                           LPR04220
      PES=PAS                                                           LPR04230
      AR=1.                                                             LPR04240
      IFDLMS=0                                                          LPR04250
      CALL PCRAT (PAS,PCS,GS,B,STEP)                                    LPR04260
      PLIM=800.                                                         LPR04270
  315 CALL ARAT (PAS,PCS,GS,PES,ISPS,D,CFS,CVS,ATS,DTS,AES,DES,IFDLMS,  LPR04280
     +IFPCS,AR,ALN,DM,PLIM,IMOTOR)                                      LPR04290
      IF ((DES.GE.(0.95*D)).OR.(PCS.LT.250)) GO TO 320                  LPR04300
      PLIM=PLIM*.99                                                     LPR04310
      GO TO 315                                                         LPR04320
C                                                                       LPR04330
  320 CONTINUE                                                          LPR04340
      TS=(PCS*D)/(2.*YIELDS)                                            LPR04350
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      AM=PI*(D/2.-TS)**2.                                               LPR04360
      BRS=0.45                                                          LPR04370
      IFAB2=2                                                           LPR04380
      IFBRS=0                                                           LPR04390
C                                                                       LPR04400
  330 AB2=DM/(DENSS*BRS)                                                LPR04410
      IF (AB2.LT.AM) GO TO 340                                          LPR04420
      J=0.85                                                            LPR04430
      APS=ATS/J                                                         LPR04440
      GEA=AM-APS                                                        LPR04450
      B=(APS/PI)**0.5                                                   LPR04460
      C=D/2-B                                                           LPR04470
      WTS=BRS*TBS                                                       LPR04480
      IF (WTS.LT.C) GO TO 360                                           LPR04490
      BRS=0.99*BRS                                                      LPR04500
      IFBRS=1                                                           LPR04510
      GO TO 330                                                         LPR04520
C                                                                       LPR04530
  340 CONTINUE                                                          LPR04540
      IFAB2=1                                                           LPR04550
      GEA=AM                                                            LPR04560
      BRS=(AB2/AM)*BRS                                                  LPR04570
      AB2=AM                                                            LPR04580
C                                                                       LPR04590
  360 CONTINUE                                                          LPR04600
      LS=VGS/GEA                                                        LPR04610
      LS=LS+D/3.+0.5                                                    LPR04620
      LB=LB+DB/6.                                                       LPR04630
      IF (AB2.EQ.AM) WTS=LS                                             LPR04640
      WCS=2.*PI*D/2.*LS*TS*DENSCS                                       LPR04650
      VOLS=AM*(LS-0.5)-(.0025*D**4.)                                    LPR04660
      NLS=(DES-DTS)/(2.*TAN(ALN))                                       LPR04670
      TWS=WPS+WCS                                                       LPR04680
      GO TO 998                                                         LPR04690
C                                                                       LPR04700
C=======================================================================LPR04710
C                                                                       LPR04720
  999 WPS=0.                                                            LPR04730
      WCS=0                                                             LPR04740
      TWS=0.                                                            LPR04750
      CFS=0.                                                            LPR04760
      CVS=0.                                                            LPR04770
      FS=0.                                                             LPR04780
      TBS=0.                                                            LPR04790
      PCS=0.                                                            LPR04800
      AB2=0.                                                            LPR04810
      WTS=0.                                                            LPR04820
      APS=0.                                                            LPR04830
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      BRS=0.                                                            LPR04840
      LS=0.                                                             LPR04850
      VOLS=0.                                                           LPR04860
      ATS=0.                                                            LPR04870
      AES=0.                                                            LPR04880
      NLS=0.                                                            LPR04890
      TS=0.                                                             LPR04900
  998 IF (IMOTOR.EQ.0) GO TO 910                                        LPR04910
      WNZ=(FB*TBB)*.00025                                               LPR04920
      WNZS=(FS*TBS)*.00025                                              LPR04930
      GO TO 915                                                         LPR04940
  910 WNZ=((FB*TBB)+(FS*TBS))*.00025                                    LPR04950
      WNZS=0.                                                           LPR04960
      NLS=0.                                                            LPR04970
  915 TCW=WCB+WCS                                                       LPR04980
      TPW=WPB+WPS                                                       LPR04990
      TRMW=WNZ+WNZS+TCW+TPW                                             LPR05000
      IFTRMW=0                                                          LPR05010
      IF (TRMW.GT.(0.75*WL)) IFTRMW=1                                   LPR05020
      IF (TRMW.LT.(0.25*WL)) IFTRMW=1                                   LPR05030
      TRML=LB+LS+NLB+NLS                                                LPR05040
      IFTRML=0                                                          LPR05050
      IF (TRML.GT.(15.*D)) IFTRML=1                                     LPR05060
      IF (IMOTOR.EQ.0) WNZS =1000000000000000000000.                    LPR05070
      IF (IMOTOR.EQ.0) NLS= 100000000000000000000.                      LPR05080
      ALN=ATAN((DEB-DTB)/(2.*NLB))                                      LPR05090
      ALN=RATODE(ALN)                                                   LPR05100
      ELB=RATODE(ELB)                                                   LPR05110
      R=R/6080.                                                         LPR05120
      CALL OUTPUT                                                       LPR05130
C                                                                       LPR05140
      WRITE (6,800)                                                     LPR05150
  800 FORMAT (1X,'DO YOU WANT TO REPEAT THIS PROBLEM? (0=NO,1=YES)')    LPR05160
      READ (5,1120) IRPT                                                LPR05170
      IF (IRPT.EQ.1) GO TO 1201                                         LPR05180
      WRITE (6,810)                                                     LPR05190
  810 FORMAT (1X,'DO YOU WANT TO RUN A NEW PROBLEM? (0=NO,1=YES)')      LPR05200
      READ (5,1120) IRPT                                                LPR05210
      IF (IRPT.EQ.1) GO TO 997                                          LPR05220
      CALL SCREEN                                                       LPR05230
      STOP                                                              LPR05240
      END                                                               LPR05250
C                                                                       LPR05260
C                                                                       LPR05270
      SUBROUTINE PRATIO (ALT,PA)                                        LPR05280
      REAL ALT,PA,PR                                                    LPR05290
      IF (ALT.GT.36089.) GO TO 10                                       LPR05300
      PR=(1.-(6.8754E-6*ALT))**5.256                                    LPR05310
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      GO TO 20                                                          LPRO5320
   10 PR=.2234*EXP(-4.806E-5*(ALT-36089.))                             LPRO5330
   20 PA=PR*14.696                                                      LPRO5340
      RETURN                                                            LPRO5350
      END                                                               LPRO5360
C                                                                       LPRO5370
C                                                                       LPRO5380
      SUBROUTINE PCRAT (PA,PC,G,B,STEP)                                 LPRO5390
      REAL PA,PC,G,B,STEP                                               LPRO5400
   10 C=((PA/PC)**((1.-G)/G)-1.)*PC                                     LPRO5410
      IF (ABS(B-C).LT.0.01) GO TO 30                                    LPRO5420
      IF (B.LT.C) GO TO 20                                              LPRO5430
      PC=PC+STEP                                                        LPRO5440
      GO TO 10                                                          LPRO5450
   20 CONTINUE                                                          LPRO5460
      PC=PC-STEP                                                        LPRO5470
      STEP=STEP/10.                                                     LPRO5480
      PC=PC+STEP                                                        LPRO5490
      GO TO 10                                                          LPRO5500
   30 CONTINUE                                                          LPRO5510
      RETURN                                                            LPRO5520
      END                                                               LPRO5530
C                                                                       LPRO5540
C                                                                       LPRO5550
      SUBROUTINE ARAT (PA,PC,G,PE,ISP,D,CF,CV,AT,DT,AE,DE,IFDLM,IFPC,AR,LPRO5560
     +ALN,DM,PLIM,IMOTOR)                                               LPRO5570
      REAL PA,PC,G,PE,ISP,D,CF,CV,AT,DT,AE,DE,B,C,ME,ALN,DM,AR,PLIM     LPRO5580
      INTEGER IFDLM,IFPC,IMOTOR                                         LPRO5590
      IFPC=0                                                            LPRO5600
   10 B=1.-(PA/PC)**((G-1.)/G)                                          LPRO5610
      C=2.*(G*G/(G-1.))*(2./(G+1.))**((G+1.)/(G-1.))                    LPRO5620
      CF=(0.96*((1.+COS(ALN))/2.)*(B*C)**0.5)+((PE-PA)*AR/PC)           LPRO5630
      CV=(ISP*32.174)/CF                                                LPRO5640
      AT=(CV*DM)/(PC*32.174)                                            LPRO5650
      DT=2*(AT/3.1415927)**0.5                                          LPRO5660
      ME=((2./(G-1.))*((PC/PE)**((G-1.)/G)-1.))**0.5                    LPRO5670
      AE1=1.+((G-1.)/2.)*ME*ME                                          LPRO5680
      AE=((1./ME)*((2./(G+1.))*AE1)**((G+1.)/(2.*(G-1.))))*AT           LPRO5690
      DE=2.*(AE/3.1415927)**0.5                                         LPRO5700
      IF ((DE.LE.D).AND.(IMOTOR.EQ.1)) GO TO 30                         LPRO5710
      IF (((PE/PA).LT.0.5).OR.((PE/PA).GT.2.2)) GO TO 30                LPRO5720
      IFDLM=1                                                           LPRO5730
      PC=PC/.999                                                        LPRO5740
      IF (PC.GT.PLIM) GO TO 20                                          LPRO5750
      GO TO 10                                                          LPRO5760
   20 PC=PC*.999                                                        LPRO5770
      PE=PE/.999                                                        LPRO5780
      IF (((PE/PA).GT.0.4).AND.((PE/PA).LT.2.5)) GO TO 25               LPRO5790
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      AE=(D/2.)**2.*3.1415927                                           LPR05800
   25 AR=AE/AT                                                          LPR05810
      IFPC=1                                                            LPR05820
      GO TO 10                                                          LPR05830
   30 CONTINUE                                                          LPR05840
      IF (PC.LT.PLIM) GO TO 40                                          LPR05850
      PC=PC*.999                                                        LPR05860
      GO TO 10                                                          LPR05870
   40 RETURN                                                            LPR05880
      END                                                               LPR05890
C                                                                       LPR05900
C                                                                       LPR05910
      SUBROUTINE SCREEN                                                 LPR05920
      WRITE (6,600)                                                     LPR05930
  600 FORMAT (1X,'CLEAR SCREEN AND ENTER "0"')                          LPR05940
      READ (5,16) ISCR                                                  LPR05950
   16 FORMAT (1I1)                                                      LPR05960
      RETURN                                                            LPR05970
      END                                                               LPR05980
C                                                                       LPR05990
C                                                                       LPR06000
      SUBROUTINE OUTPUT                                                 LPR06010
      REAL WPB,WCB,TWB,CFB,CVB,FB,TBB,RB,PCB,ABB,WTB,APB,LB,VOLB,ATB,BRBLPR06020
      REAL WPS,WCS,TWS,CFS,CVS,FS,TBS,PCS,ABS,WTS,APS,LS,VOLS,ATS,BRS   LPR06030
      REAL NLB,AEB,WNZ,TPW,TCW,TRMW,TRML,T,AES                          LPR06040
      REAL VBF,VBI,YIELD,DENSC,ALN,ER,D,R,WL,A,ELB,ISPB                 LPR06050
      REAL DENSB,GB,LALT,DRAGS,TALT,ISPS,GS,DENSS,DB                    LPR06060
      REAL YIELDS,DENSCS,TS,WNZS,NLS,ALTBN,ALTSN                        LPR06070
      INTEGER IFBRB,IFDLMB,IFAB2,IFBRS,IFPCB,IFTRMW,IFBSTO,IFTRML,IFPCS LPR06080
      INTEGER IMOTOR                                                    LPR06090
      COMMON WPB,WCB,TWB,CFB,CVB,FB,TBB,RB,PCB,ABB,WTB,APB,LB,VOLB      LPR06100
      COMMON ATB,BRB,NLB,AEB,WNZ,TPW,TCW,TRMW,TRML,T                    LPR06110
      COMMON WPS,WCS,TWS,CFS,CVS,FS,TBS,PCS,AB2,WTS,APS,LS,VOLS,ATS,BRS LPR06120
      COMMON VBF,VBI,YIELD,DENSC,ALN,ER,D,R,WL,A,ELB,ISPB               LPR06130
      COMMON DENSB,GB,LALT,DRAGS,TALT,ISPS,GS,DENSS,DB                  LPR06140
      COMMON YIELDS,DENSCS,TS,WNZS,NLS,AES,ALTBN,ALTSN                  LPR06150
      COMMON IFBRB,IFDLMB,IFAB2,IFBRS,IFPCB,IFTRMW,IFBSTO,IFTRML,IFPCS  LPR06160
      COMMON IFDLMS,IMOTOR                                              LPR06170
      WRITE (6,1000)                                                    LPR06180
 1000 FORMAT (35X,'BOOSTER',T55,'SUSTAINER')                            LPR06190
      WRITE (6,1010) WPB,WPS,WCB,WCS,TWB,TWS,CFB,CFS,CVB,CVS,FB,FS      LPR06200
 1010 FORMAT (1X,'PROPELLANT WEIGHT',T35,F7.2,' LBS',T55,F7.2,' LBS'/,  LPR06210
     +1X,'CASING WEIGHT',T35,F7.2,' LBS',T55,F7.2,' LBS'/,              LPR06220
     +1X,'TOTAL WEIGHT',T35,F7.2,' LBS',T55,F7.2,' LBS'/,               LPR06230
     +1X,'THRUST COEFFICIENT',T35,F7.4,T55,F7.4/,                       LPR06240
     +1X,'CHARACTERISTIC VELOCITY',T35,F7.1,' FT/SEC',T55,F7.1,' FT/SEC'LPR06250
     +/,1X,'THRUST',T35,F7.1,' LBS',T55,F7.1,' LBS')                    LPR06260
      WRITE (6,1020) TBB,TBS,RB,PCB,PCS,ABB,AB2,WTB,WTS,APB,APS         LPR06270
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1020  FORMAT (1X,'BURN TIME',T35,F7.3,' SEC',T55,F7.3,' SEC'/,          LPRO6280
     +1X,'HORIZONTAL BURNOUT RANGE',T35,F7.0,' FEET'/,                  LPRO6290
     +1X,'CHAMBER PRESSURE',T35,F7.2,' PSI',T55,F7.2,' PSI'/,           LPRO6300
     +1X,'GRAIN BURN AREA',T34,F8.3,' SQ.IN',T54,F8.3,' SQ.IN'/,        LPRO6310
     +1X,'GRAIN WEB THICKNESS',T35,F7.3,' IN',T55,F7.3,' IN'/,          LPRO6320
     +1X,'GRAIN PORT AREA',T35,F7.3,' SQ.IN',T55,F7.3,' SQ.IN')         LPRO6330
      WRITE (6,1030) BRB,BRS,LB,LS,VOLB,VOLS,ATB,ATS,AEB,AES,NLB,NLS    LPRO6340
1030  FORMAT (1X,'REQUIRED BURN RATE',T35,F7.3,' IN/SEC',T55,F7.3,' IN/SLPRO6350
     +EC'/,1X,'MOTOR CASE LENGTH',T35,F7.2,' IN',T55,F7.2,' IN'/,       LPRO6360
     +1X,'MOTOR CASE VOLUME',T33,F9.2,' CU.IN',T53,F9.2,' CU.IN'/,      LPRO6370
     +1X,'NOZZLE THROAT AREA',T35,F7.3,' SQ.IN',T55,F7.3,' SQ.IN'/,     LPRO6380
     +1X,'NOZZLE EXIT AREA',T35,F7.3,' SQ.IN',T55,F7.3,' SQ.IN'/,       LPRO6390
     +1X,'NOZZLE LENGTH',T35,F7.3,' IN',T55,F7.3,' IN')                 LPRO6400
      WRITE (6,1040) WNZ,WNZS,T,TS,TCW,TPW,TRMW,TRML                    LPRO6410
1040  FORMAT (1X,'NOZZLE WEIGHT',T35,F7.2,' LBS',T55,F7.2,' LBS'/,       LPRO6420
     +1X,'CASE THICKNESS',T35,F7.5,' IN',T55,F7.5,' IN'/,               LPRO6430
     +1X,'TOTAL CASE WEIGHT',T45,F7.2,' LBS'/,                          LPRO6440
     +1X,'TOTAL PROPELLANT WEIGHT',T45,F7.2,' LBS'/,                    LPRO6450
     +1X,'TOTAL ROCKET MOTOR WEIGHT',T45,F7.2,' LBS'/,                  LPRO6460
     +1X,'TOTAL ROCKET MOTOR LENGTH',T45,F7.2,' IN')                    LPRO6470
      IF (IFBSTO.EQ.0) GO TO 1209                                       LPRO6480
      IF (IFPCS.EQ.0) WRITE (6,1205)                                    LPRO6490
1205  FORMAT (/1X,'SUSTAINER NOT CALCULATED SINCE THE BOOSTER BURNOUT RALPRO6500
     +NGE EXCEEDS'/,1X,'THE DESIGN RANGE.')                             LPRO6510
      IF (IFPCS.EQ.2) WRITE (6,1206)                                    LPRO6520
1206  FORMAT (/1X,'SUSTAINER NOT CALCULATED; THE BOOSTER NOZZLE DESIGN PLPRO6530
     +REVENTS'/,1X,'SUSTAINER OPERATION.  RECOMMEND STAGING OR INDEPENDELPRO6540
     +NT NOZZLES.')                                                     LPRO6550
1209  IF (IFBRB.EQ.1) WRITE (6,1210)                                    LPRO6560
1210  FORMAT (/1X,'BOOSTER BURN RATE WAS ADJUSTED TO CORRESPOND WITH THELPRO6570
     + WEB THICKNESS.')                                                 LPRO6580
      IF (IFDLMB.EQ.1) WRITE (6,1220)                                   LPRO6590
1220  FORMAT (/1X,'THE BOOSTER NOZZLE DESIGN WAS RESTRICTED DUE TO THE MLPRO6600
     +ISSILE DIAMETER.')                                                LPRO6610
      IF (IFPCB.EQ.1) WRITE (6,1230)                                    LPRO6620
1230  FORMAT (/1X,'BOOSTER NOZZLE DESIGN IS NOT OPTIMUM DUE TO EXCESSIVELPRO6630
     + BOOSTER CHAMBER'/,1X,'PRESSURES.')                               LPRO6640
      IF (IFDLMS.EQ.1) WRITE (6,1233)                                   LPRO6650
1233  FORMAT (/1X,'THE SUSTAINER NOZZLE DESIGN WAS RESTRICTED DUE TO THELPRO6660
     + MISSILE DIAMETER.')                                              LPRO6670
      IF (IFPCS.EQ.1) WRITE (6,1235)                                    LPRO6680
1235  FORMAT (/1X,'SUSTAINER NOZZLE DESIGN IS NOT OPTIMUM DUE TO EXCESSI LPRO6690
     +VE SUSTAINER'/,1X,'CHAMBER PRESSURES.')                           LPRO6700
      IF (IFAB2.EQ.2) WRITE (6,1241)                                    LPRO6710
1241  FORMAT (/1X,'THE SUSTAINER MOTOR HAS A CORE-BURNING GRAIN.')       LPRO6720
      IF (IFBRS.EQ.1) WRITE (6,1245)                                    LPRO6730
1245  FORMAT (/1X,'SUSTAINER BURN RATE WAS ADJUSTED TO CORRESPOND WITH T LPRO6740
     +HE WEB THICKNESS.')                                               LPRO6750
```

```
      IF (IFAB2.EQ.1) WRITE (6,1250)                                    LPR06760
 1250 FORMAT (/1X,'THE SUSTAINER MOTOR HAS AN END-BURNING GRAIN.')      LPR06770
      IF (IFTRMW.EQ.1) WRITE (6,1260)                                   LPR06780
 1260 FORMAT (/1X,'REESTIMATION OF LAUNCH WEIGHT IS REQUIRED FOR THESE MLPR06790
     +ISSILE PERFORMANCE'/,1X,'PARAMETERS.')                            LPR06800
      IF (IFTRML.EQ.1) WRITE (6,1270)                                   LPR06810
 1270 FORMAT (/1X,'ENLARGEMENT OF DIAMETER IS RECOMMENDED DUE TO A VERY LPR06820
     +HIGH LENGTH-TO-DIAMETER'/,1X,'RATIO FOR THE MOTOR.')              LPR06830
      WRITE (6,1300)                                                    LPR06840
 1300 FORMAT (/1X,'DO YOU WANT TO HAVE THIS AS HARDCOPY OUTPUT? (0=NO,1=LPR06850
     +YES)')                                                            LPR06860
      READ (5,1310) ICOPY                                               LPR06870
 1310 FORMAT (I1)                                                       LPR06880
      IF (ICOPY.EQ.0) GO TO 1500                                        LPR06890
                                                                        LPR06900
      IF (IMOTOR.EQ.0) WRITE (8,208)                                    LPR06910
  208 FORMAT (//1X,'INTEGRAL MOTORS (COMMON NOZZLE)')                   LPR06920
      IF (IMOTOR.EQ.1) WRITE (8,209)                                    LPR06930
  209 FORMAT (//1X,'STAGED MOTORS (INDEPENDENT NOZZLES)')               LPR06940
      WRITE (8,210) LALT,WL,VBI,ELB,A,VBF,DRAGS,R,TALT,ISPB,DENSB,GB    LPR06950
  210 FORMAT (1X,'SUMMARY OF INPUT PARAMETERS=========================',LPR06960
     +/5X,' 1) LAUNCH ALTITUDE',T45,F12.1,' FEET',                      LPR06970
     +/5X,' 2) LAUNCH WEIGHT',T45,F12.2,' POUNDS',                      LPR06980
     +/5X,' 3) LAUNCH VELOCITY',T45,F12.1,' FT/SEC',                    LPR06990
     +/5X,' 4) LAUNCH ANGLE',T45,F12.1,' DEGREES',                      LPR07000
     +/5X,' 5) AVERAGE ACCELERATION',T45,F12.2,' G"S',                  LPR07010
     +/5X,' 6) CRUISE VELOCITY',T45,F12.1,' FT/SEC',                    LPR07020
     +/5X,' 7) DRAG AT CRUISE VELOCITY',T45,F12.1,' POUNDS',            LPR07030
     +/5X,' 8) MAXIMUM RANGE',T45,F12.0,' MILES',                       LPR07040
     +/5X,' 9) FINAL (TARGET) ALTITUDE',T45,F12.1,' FEET',              LPR07050
     +/5X,'10) BOOSTER PROPELLANT SPECIFIC IMPULSE',T45,F12.1,' SEC',   LPR07060
     +/5X,'11) BOOSTER PROPELLANT DENSITY',T45,F12.4,' LBS/CU.IN',      LPR07070
     +/5X,'12) BOOSTER EXHAUST SPECIFIC HEAT RATIO',T50,F7.5)           LPR07080
      WRITE (8,220) ISPS,DENSS,GS,ALN                                   LPR07090
  220 FORMAT (5X,'13) SUSTAINER PROPELLANT SPECIFIC IMPULSE',T50,F7.1,  LPR07100
     +' SEC',                                                           LPR07110
     +/5X,'14) SUSTAINER PROPELLANT DENSITY',T45,F12.4,' LBS/CU.IN',    LPR07120
     +/5X,'15) SUSTAINER EXHAUST SPECIFIC HEAT RATIO',T50,F7.5,         LPR07130
     +/5X,'16) NOZZLE HALF ANGLE',T45,F12.2,' DEGREES')                 LPR07140
      IF (IMOTOR.EQ.1) GO TO 240                                        LPR07150
      WRITE (8,230) ALTBN,ER,DB,YIELD,DENSC                             LPR07160
  230 FORMAT (5X,'17) NOZZLE DESIGN ALTITUDE',T45,F12.1,' FEET',        LPR07170
     +/5X,'18) NOZZLE EROSION RATE',T45,F12.5,' IN/SEC',                LPR07180
     +/5X,'19) MISSILE DIAMETER',T45,F12.1,' INCHES',                   LPR07190
     +/5X,'20) YIELD STRENGTH OF CASE MATERIAL',T45,F12.1,' PSI',       LPR07200
     +/5X,'21) DENSITY OF CASE MATERIAL',T45,F12.4,' LBS/CU.IN')        LPR07210
      GO TO 249                                                         LPR07220
  240 WRITE (8,245) ALTBN,DB,YIELD,DENSC,ALTSN,D,YIELDS,DENSCS          LPR07230
```

```
245 FORMAT (5X,'17) BOOSTER DESIGN ALTITUDE',T45,F12.1,' FEET',          LPRO7240
   +/5X,'18) BOOSTER DIAMETER',T45,F12.2,' INCHES',                      LPRO7250
   +/5X,'19) YIELD STRENGTH OF BOOSTER CASE',T45,F12.1,' PSI',           LPRO7260
   +/5X,'20) DENSITY OF BOOSTER CASE MATERIAL',T45,F12.4,' LBS/CU.IN',LPRO7270
   +/5X,'21) SUSTAINER DESIGN ALTITUDE',T45,F12.1,' FEET',               LPRO7280
   +/5X,'22) SUSTAINER DIAMETER',T45,F12.2,' INCHES',                    LPRO7290
   +/5X,'23) YIELD STRENGTH OF SUSTAINER CASE',T45,F12.1,' PSI',         LPRO7300
   +/5X,'24) DENSITY OF SUSTAINER CASE MATERIAL',T45,F12.4,' LBS/CU.INLPRO7310
   +'/)                                                                  LPRO7320
249 CONTINUE                                                             LPRO7330
    WRITE (8,1000)                                                       LPRO7340
    WRITE (8,1010) WPB,WPS,WCB,WCS,TWB,TWS,CFB,CFS,CVB,CVS,FB,FS         LPRO7350
    WRITE (8,1020) TBB,TBS,RB,PCB,PCS,ABB,AB2,WTB,WTS,APB,APS            LPRO7360
    WRITE (8,1030) BRB,BRS,LB,LS,VOLB,VOLS,ATB,ATS,AEB,AES,NLB,NLS       LPRO7370
    WRITE (8,1040) WNZ,WNZS,T,TS,TCW,TPW,TRMW,TRML                       LPRO7380
    IF (IFBSTO.EQ.0) GO TO 250                                           LPRO7390
    IF (IFPCS.EQ.0) WRITE (8,1205)                                       LPRO7400
    IF (IFPCS.EQ.2) WRITE (8,1206)                                       LPRO7410
250 IF (IFBRB.EQ.1) WRITE (8,1210)                                       LPRO7420
    IF (IFDLMB.EQ.1) WRITE (8,1220)                                      LPRO7430
    IF (IFPCB.EQ.1) WRITE (8,1230)                                       LPRO7440
    IF (IFDLMS.EQ.1) WRITE (8,1233)                                      LPRO7450
    IF (IFPCS.EQ.1) WRITE (8,1235)                                       LPRO7460
    IF (IFAB2.EQ.2) WRITE (8,1241)                                       LPRO7470
    IF (IFBRS.EQ.1) WRITE (8,1245)                                       LPRO7480
    IF (IFAB2.EQ.1) WRITE (8,1250)                                       LPRO7490
    IF (IFTRMW.EQ.1) WRITE (8,1260)                                      LPRO7500
    IF (IFTRML.EQ.1) WRITE (8,1270)                                      LPRO7510
1500 CONTINUE                                                            LPRO7520
    RETURN                                                               LPRO7530
    END                                                                  LPRO7540
```

# APPENDIX G. AERODYNAMIC COEFFICIENTS PROGRAM LISTING

This program is divided into three major subdivisions; the executive routines, the FORTRAN II/IV computational program, and the FORTRAN IV plotting program. The executive routines are used to establish the required file definitions, initiate operation of the computational program, supervise the transfer of data to the plotting program, and provide operational information to the user at appropriate times.

The computational program, LAERO1 FORTRAN, consists of five subprogram divisions. The MAIN program accepts the input data, conducts calc lations not done by other subroutines, formats the calculated data and provides the output data to the user, the printer file, and the plot program data file. Subroutine GEOSUB calculates the missile wetted area and the Reynolds number per foot based on the flight altitude. Subroutine CLASUB calculates the aerodynamic surface lift-curve slopes. Subroutine CATSUB calculates center of pressure locations, cross-flow drag coefficients, and interference factors. Subroutine SCREEN prompts the user to clear the terminal screen for proper positioning of the output.

The plot program, AEROPLOT FORTRAN, is structured for direct submission to the MVS batch reader from the 3278 terminal. No cards need to be punched or read. However, attention must be given to the correct JCL accounting data in the first line of the program; those shown in the listing are for illustrative purposes only. This program receives the data from the computational program and produces a group of six charts for each Mach number entered. The plots represent the relationships of Cl to alpha, Cm, Cn, Cd, Ca, and Cdi. The program can produce up to 24 sets of plots for a single run.

```
FILE: LAERO1  EXEC      A   NAVAL POSTGRADUATE SCHOOL

FILEDEF 08 DISK LAERO1 OUTPUT A0 (RECFM VA BLOCK 133 PERM
FILEDEF 07 DISK LAERO1 PLOT A0 (RECFM VA BLOCK 80 PERM
&BEGTYPE
YOU WILL HAVE THE OPPORTUNITY TO OBTAIN BOTH A HARDCOPY
PRINTOUT AND A SET OF PLOTS FOR ONE SET OF INPUT PARAMETERS
EACH TIME YOU ENTER THIS PROGRAM.  THE PROGRAM MAY BE
RE-RUN CONTINUOUSLY AND YOU WILL HAVE THE OPTION TO CHANGE
INPUT PARAMETERS FOR EACH SUCCESSIVE RUN, BUT YOU CAN
OBTAIN THE PRINTOUT AND PLOTS PERTAINING TO THE LAST RUN
ONLY.  IF ADDITIONAL OUTPUT IS REQUIRED, RE-ENTER THE
PROGRAM.
&END
LOAD LAERO1
START
&BEGTYPE

TO OBTAIN THE HARDCOPY PRINTOUT OF THE DATA TABLES, TYPE
AND ENTER:

                          LAERO1PR


TO OBTAIN THE VERSATEC PLOT OF THE TABULAR DATA, TYPE AND
ENTER:

                          LAERO1PL

&END
```

```
FILE:  LAERO1PR  EXEC    A   NAVAL POSTGRADUATE SCHOOL

PRINT LAERO1 OUTPUT (LINECOUN 70
&BEGTYPE
THE OUTPUT WILL BE PRINTED ON THE VM PRINTER IN ROOM 140
AND WILL BE IDENTIFIED WITH YOUR USER NUMBER AND LAST NAME.
IT USUALLY REQUIRES SEVERAL MINUTES TO OBTAIN THE PRINTOUT.
&END
```

```
FILE:  LAERO1PL EXEC    A   NAVAL POSTGRADUATE SCHOOL

COPY LAERO1 PLOT A LAERO  PLOTDATA A PLOT LAERO1 A
EXEC SUBMIT PLOT LAERO1 A
ERASE PLOT LAERO1 A
&BEGTYPE
THE PLOT WILL BE DRAWN IN THE COMPUTER ROOM AND PLACED OVER
THE ALPHABETIZED OUTPUT FILE IN ROOM 140.  IT WILL BE
IDENTIFIED BY "AEROFILE" AND USUALLY REQUIRES MANY MINUTES
(HOURS, DAYS) TO OBTAIN.
&END
```

```
C  AERO FORTRAN                                                         LAE00040
C  26 MAY 1981                                                          LAE00050
C  PLOTTING OUTPUT FACILITY INSTALLED                                   LAE00060
C                                                                       LAE00070
C  AERO1 CONSISTS OF A MAIN PROGRAM AND THREE SUBROUTINES.  THE INPUTS  LAE00080
C  ARE THE GEOMETRIC CHARACTERISTICS OF THE MISSILE, THE FLIGHT COND-   LAE00090
C  ITIONS, ENGINE AND INLET TYPE AND THE PROTUBERANCE DRAG.  THE OUTPUT LAE00100
C  CONSISTS OF THE AERODYNAMIC COEFFICIENTS FOR LIFT, DRAG AND MOMENT.  LAE00110
C  THE COMPONENT CONTRIBUTION TO THESE COEFFICIENTS, AND THE COMPONENT  LAE00120
C  AND OVERALL CENTERS OF PRESSURE ARE ALSO DETERMINED.                 LAE00130
C                                                                       LAE00140
C  AERO1 IS A MODIFICATION BY LT. D. R. REDMON OF THE PROGRAM AEROCF    LAE00150
C  WHICH WAS DEVELOPED AT THE NAVAL AIR DEVELOPEMENT CENTER BY          LAE00160
C  MR. F. A. KUSTER, JR.  THE PROGRAM IS ESSENTIALLY AS WRITTEN EXCEPT  LAE00170
C  FOR CALCULATION OF PLANFORM AREAS AND CENTROIDS.  IT WAS FURTHER     LAE00180
C  ADAPTED BY LT. M. D. SULLIVAN FOR USE AS AN INTERACTIVE PROGRAM ON   LAE00190
C  THE NAVAL POSTGRADUATE SCHOOL IBM 3033 VM/370 SYSTEM.                LAE00200
C                                                                       LAE00210
C  THE MAIN PROGRAM ASSUMES THE CONTROL SURFACES IS THE TAIL.  THIS IS  LAE00220
C  REGARDLESS OF THE METHOD OF CONTROL (WING, TAIL, CANARD).  BECAUSE OFLAE00230
C  THIS, CARE MUST BE TAKEN TO INPUT THE "RIGHT" DATA FOR THE TAIL.  FORLAE00240
C  INSTANCE, IF THE MISSILE IS A WING-CONTROL MISSILE, THE WING DATA    LAE00250
C  MUST BE INPUT FOR THE TAIL AND THE TAIL DATA INPUT FOR THE WING.     LAE00260
C                                                                       LAE00270
      DIMENSION XVXM(24),XDT(24),XAL(48)                                LAE00280
      DIMENSION CLM(24,24,24),CDM(24,24,24),CMM(24,24,24),CAM(24,24,24) LAE00290
      DIMENSION CNM(24,24,24),CDIM(24,24,24)                            LAE00300
      COMMON REFTI,REFT,SSUBS,XLOB,ZF,VXM,IZZY,LLKK,LLLL,NSURF          LAE00310
      COMMON ICSC, INOSE,ISWPW,IAFBW,ISWPW2,IAFBW2,ISWPT,IAFBT,IDUM1,   LAE00320
     *CLAMT,CLAMW,CLAMW2,D,XLNOSE,BT,BW,BW2,CROOTW,CTOOTT,CTOOW2,       LAE00330
     *ST,SW,SW2,TOVCW,TOVCW2,TOVCT,XLAMT,XLAMW,XLAMW2,                  LAE00340
     *XMACW,XMACW2,XMACT,XWING,XWING2,XTAIL,HT,XL,AREA,XREF,            LAE00350
     *ISWEPW,ISWEPT,ISWEP2,NWING,NTAIL,NWING2,ENGINE,ENLET,BETA,DBASE,  LAE00360
     *DJET,XLABOD                                                       LAE00370
      COMMON ART,ARW,ARW2,BAR,BCOLAM,BETA1,B1,CLALT,CLALW,CLALW2,CLAL1, LAE00380
     *COLAM,CROOT,IAFB,ISWP,TOVC,ODC,XBCRBW,XBCRWB,XKBT,XKBW,XKTB,XKTBT,LAE00390
     *XKWB,XKWBI,ISWP1,RATIO,XLAM1,XMAC,D1                              LAE00400
      CDW2=0.0                                                          LAE00410
      CDOW2=0.0                                                         LAE00420
      IL = 0                                                            LAE00430
      IABC=0                                                            LAE00440
      ISWPW2=0                                                          LAE00450
      IAFBW2=0                                                          LAE00460
      XLAMW2=.0                                                         LAE00470
      CLAMW2=.0                                                         LAE00480
      BW2=.0                                                            LAE00490
      CROOW2= .0                                                        LAE00500
      SW2=.0                                                            LAE00510
```

```
      XMACW2=.0
      XWING2=.0
      ISWEP2=0
      NWING2=0
C+++++++++++++++++++++++++++++++++++++++++
C   THE FOLLOWING INSTRUCTIONS ARE FOR THE PLOT CAPABILITY
      CLMAX=0.
      CLMIN=0.
      DO 4000 I=1,24
        XAL(I)=000.
        XDT(I)=000.
        XVXM(I)=000.
        DO 4000 J=1,24
          DO 4000 K=1,24
            CLM(I,J,K)=000.
            CDM(I,J,K)=000.
            CMM(I,J,K)=000.
            CAM(I,J,K)=000.
            CNM(I,J,K)=000.
            CDIM(I,J,K)=000.
 4000       CONTINUE
C+++++++++++++++++++++++++++++++++++++++++
 1000 FORMAT(2I5,7F10.5)
 1010 FORMAT(6I5)
 1020 FORMAT(15A4)
 1030 FORMAT(3F10.3,6I2)
 1040 WRITE (6,1050)
 1050 FORMAT(1X,'INPUT TITLE')
      READ 1020, TITL1,TITL2,TITL3,TITL4,TITL5,TITL6,TITL7,TITL8,TITL9,
     *TITL0,TITL01,TITL02,TITL03,TITL04,TITL05
 1060 FORMAT (I2)
 1070 FORMAT (F10.3)
 1080 WRITE (6,1090)
 1090 FORMAT(/,1X,'NOTE          '/,
     *1X,'UNLESS OTHERWISE INDICATED, INPUT THE FOLLOWING DATA AS'/,
     *1X,'TWO-DIGIT INTEGERS; I.E., THREE=03.'/)
60001 WRITE (6,10010)
10010 FORMAT(1X,'INPUT CONTROL CONSTANT, 01=TAIL CONTROL, 02=WING CONTRO
     *L, 03=CANARD CONTROL')
      READ 1060,ICSC
      IF(IABC.EQ.1)GO TO 1100
60002 WRITE (6,10020)
10020 FORMAT(1X,'INPUT NOSE SHAPE, 01=ELLIPSOID, 02=OGIVE, 03=CONE')
      READ 1060,INOSE
      IF(IABC.EQ.1)GO TO 1100
60003 WRITE (6,10030)
10030 FORMAT(1X,'INPUT NUMBER OF CONTROL DEFLECTIONS (LESS THAN 25)')
      READ 1060,IDT
```

```
      DO 10000 I=1,IDT                                                  LAE01000
      WRITE (6,10450)                                                   LAE01010
10450 FORMAT(1X,'****INPUT CONTROL DEFLECTION (DECIMAL NUMBER)')        LAE01020
10000 READ 1070, XDT(I)                                                 LAE01030
      IF(IABC.EQ.1)GO TO 1100                                           LAE01040
60004 WRITE (6,10040)                                                   LAE01050
10040 FORMAT(1X,'INPUT NUMBER OF MACH NUMBERS (LESS THAN 25)')          LAE01060
      READ 1060,IM                                                      LAE01070
      DO 20000 I=1,IM                                                   LAE01080
      WRITE (6,10460)                                                   LAE01090
10460 FORMAT(1X,'****INPUT MACH NUMBER (DECIMAL NUMBER)')               LAE01100
20000 READ 1070, XVXM(I)                                                LAE01110
      IF(IABC.EQ.1)GO TO 1100                                           LAE01120
60005 WRITE (6,10050)                                                   LAE01130
10050 FORMAT(1X,'INPUT NUMBER OF ANGLES OF ATTACK (LESS THAN 25)')      LAE01140
      READ 1060,IAL                                                     LAE01150
      ICL=IAL                                                           LAE01160
      DO 30000 I=1,IAL                                                  LAE01170
      WRITE (6,10470)                                                   LAE01180
10470 FORMAT(1X,'****INPUT ANGLE OF ATTACK (DECIMAL NUMBER)')           LAE01190
30000 READ 1070, XAL(I)                                                 LAE01200
      IF(IABC.EQ.1)GO TO 1100                                           LAE01210
60006 WRITE (6,10060)                                                   LAE01220
10060 FORMAT(1X,'INPUT NUMBER OF CONFIGURATIONS')                       LAE01230
      READ 1060,NBODY                                                   LAE01240
      IF(IABC.EQ.1)GO TO 1100                                           LAE01250
60007 WRITE (6,10070)                                                   LAE01260
10070 FORMAT(1X,'INPUT, 01=NON-DELTA WING, 02=DELTA WING')              LAE01270
      READ 1060, ISWPW                                                  LAE01280
      IF(IABC.EQ.1)GO TO 1100                                           LAE01290
60008 WRITE (6,10080)                                                   LAE01300
10080 FORMAT(1X,'00=NO BODY AFTER WING, 01=BODY AFTER WING')            LAE01310
      READ 1060, IAFBW                                                  LAE01320
      IF(IABC.EQ.1)GO TO 1100                                           LAE01330
60009 WRITE (6,10090)                                                   LAE01340
10090 FORMAT(1X,'INPUT WING SWEEP CONSTANT')                            LAE01350
      WRITE (6,55001)                                                   LAE01360
55001 FORMAT(1X,'IF DELTA PLANFORM ENTER 00; OTHERWISE,'/,              LAE01370
     *1X,'00=UNSWEPT LEADING EDGE, 01=SWEPT LEADING EDGE')              LAE01380
      READ 1060,ISWEPW                                                  LAE01390
      IF(IABC.EQ.1)GO TO 1100                                           LAE01400
60010 WRITE (6,10100)                                                   LAE01410
10100 FORMAT(1X,'INPUT NUMBER OF WINGS')                                LAE01420
      READ 1060,NWING                                                   LAE01430
      IF(IABC.EQ.1)GO TO 1100                                           LAE01440
60011 WRITE (6,10110)                                                   LAE01450
10110 FORMAT(1X,'INPUT, 01=NON-DELTA TAIL, 02=DELTA TAIL')              LAE01460
      READ 1060, ISWPT                                                  LAE01470
```

```
      IF(IABC.EQ.1)GO TO 1100                                           LAE01480
60012 WRITE (6,10120)                                                   LAE01490
10120 FORMAT(1X,'00=NO BODY AFTER TAIL, 01=BODY AFTER TAIL')            LAE01500
      READ 1060,IAFBT                                                   LAE01510
      IF(IABC.EQ.1)GO TO 1100                                           LAE01520
60013 WRITE (6,10130)                                                   LAE01530
10130 FORMAT( 1X,'INPUT TAIL SWEEP CONSTANT')                           LAE01540
      WRITE (6,55001)                                                   LAE01550
      READ 1060, ISWEPT                                                 LAE01560
      IF(IABC.EQ.1)GO TO 1100                                           LAE01570
60014 WRITE (6,10140)                                                   LAE01580
10140 FORMAT(1X,'INPUT NUMBER OF TAILS')                                LAE01590
      READ 1060, NTAIL                                                  LAE01600
      IF(IABC.EQ.1)GO TO 1100                                           LAE01610
90002 WRITE (6,99998)                                                   LAE01620
99998 FORMAT(/,1X,'NOTE                    '/                           LAE01630
     *1X,'INPUT THE FOLLOWING DATA AS DECIMAL NUMBERS '/)               LAE01640
60015 WRITE (6,10150)                                                   LAE01650
10150 FORMAT(1X,'INPUT TIP-TO-CHORD RATIO OF WING')                     LAE01660
      READ 1070,XLAMW                                                   LAE01670
      IF(IABC.EQ.1)GO TO 1100                                           LAE01680
60016 WRITE (6,10160)                                                   LAE01690
10160 FORMAT(1X,'INPUT LEADING EDGE SWEEP OF WING,(DEGS)')              LAE01700
      READ 1070, CLAMW                                                  LAE01710
      IF(IABC.EQ.1)GO TO 1100                                           LAE01720
60017 WRITE (6,10170)                                                   LAE01730
10170 FORMAT(1X,'INPUT WING SPAN, INCLUDE BODY')                        LAE01740
      READ 1070, BW                                                     LAE01750
      IF(IABC.EQ.1)GO TO 1100                                           LAE01760
60018 WRITE (6,10180)                                                   LAE01770
10180 FORMAT( 1X,'INPUT WING ROOT CHORD (AT BODY JUNCTION)')            LAE01780
      READ 1070, CROOTW                                                 LAE01790
      IF(IABC.EQ.1)GO TO 1100                                           LAE01800
60019 WRITE (6,10190)                                                   LAE01810
10190 FORMAT(1X,'INPUT EXPOSED WING AREA (2 PANELS)')                   LAE01820
      READ 1070,SW                                                      LAE01830
      IF(IABC.EQ.1)GO TO 1100                                           LAE01840
60020 WRITE (6,10200)                                                   LAE01850
10200 FORMAT( 1X,'INPUT WING MEAN GEOMETRIC CHORD')                     LAE01860
      READ 1070, XMACW                                                  LAE01870
      IF(IABC.EQ.1)GO TO 1100                                           LAE01880
60021 WRITE (6,10210)                                                   LAE01890
10210 FORMAT(1X,'INPUT DISTANCE FROM NOSE TO WING LEADING EDGE')        LAE01900
      READ 1070, XWING                                                  LAE01910
      IF(IABC.EQ.1)GO TO 1100                                           LAE01920
60022 WRITE (6,10220)                                                   LAE01930
10220 FORMAT( 1X,'INPUT WING THICKNESS-TC-CHORD RATIO')                 LAE01940
      READ 1070, TOVCW                                                  LAE01950
```

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      IF(IABC.EQ.1)GO TO 1100                                           LAE01960
60023 WRITE (6,10230)                                                   LAE01970
10230 FORMAT(1X,'INPUT TIP-TO-ROOT CHORD RATIO OF TAIL')                LAE01980
      READ 1070, XLAMT                                                  LAE01990
      IF(IABC.EQ.1)GO TO 1100                                           LAE02000
60024 WRITE (6,10240)                                                   LAE02010
10240 FORMAT(1X,'INPUT TAIL LEADING EDGE SWEEP (DEGS)')                 LAE02020
      READ 1070, CLAMT                                                  LAE02030
      IF(IABC.EQ.1)GO TO 1100                                           LAE02040
60025 WRITE (6,10250)                                                   LAE02050
10250 FORMAT(1X,'INPUT TAIL SPAN, INCLUDING BODY')                      LAE02060
      READ 1070,BT                                                      LAE02070
      IF(IABC.EQ.1)GO TO 1100                                           LAE02080
60026 WRITE (6,10260)                                                   LAE02090
10260 FORMAT(1X,'INPUT TAIL ROOT CHORD')                                LAE02100
      READ 1070, CROOTT                                                 LAE02110
      IF(IABC.EQ.1)GO TO 1100                                           LAE02120
60027 WRITE (6,10270)                                                   LAE02130
10270 FORMAT(1X,'INPUT EXPOSED TAIL AREA (2 PANELS)')                   LAE02140
      READ 1070,ST                                                      LAE02150
      IF(IABC.EQ.1)GO TO 1100                                           LAE02160
60028 WRITE (6,10280)                                                   LAE02170
10280 FORMAT(1X,'INPUT TAIL MEAN GEOMETRIC CHORD')                      LAE02180
      READ 1070, XMACT                                                  LAE02190
      IF(IABC.EQ.1)GO TO 1100                                           LAE02200
60029 WRITE (6,10290)                                                   LAE02210
10290 FORMAT(1X,'INPUT DISTANCE FROM NOSE TO TAIL LEADING EDGE')        LAE02220
      READ 1070,XTAIL                                                   LAE02230
      IF(IABC.EQ.1)GO TO 1100                                           LAE02240
60030 WRITE (6,10300)                                                   LAE02250
10300 FORMAT(1X,'INPUT TAIL THICKNESS-TC-CHORD RATIO')                  LAE02260
      READ 1070, TOVCT                                                  LAE02270
      IF(IABC.EQ.1)GO TO 1100                                           LAE02280
60031 WRITE (6,10310)                                                   LAE02290
10310 FORMAT(1X,'INPUT ALTITUDE')                                       LAE02300
      READ 1070, HT                                                     LAE02310
      IF(IABC.EQ.1)GO TO 1100                                           LAE02320
60032 WRITE (6,10320)                                                   LAE02330
10320 FORMAT(1X,'INPUT BODY DIAMETER')                                  LAE02340
      READ 1070, D                                                      LAE02350
      IF(IABC.EQ.1)GO TO 1100                                           LAE02360
60033 WRITE (6,10330)                                                   LAE02370
10330 FORMAT(1X,'INPUT MISSILE LENGTH')                                 LAE02380
      READ 1070,XL                                                      LAE02390
      IF(IABC.EQ.1)GO TO 1100                                           LAE02400
60034 WRITE (6,10340)                                                   LAE02410
10340 FORMAT(1X,'INPUT NOSE LENGTH')                                    LAE02420
      READ 1070,XLNOSE                                                  LAE02430
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      IF(IABC.EQ.1)GO TO 1100                                           LAE02440
60035 WRITE (6,10350)                                                   LAE02450
10350 FORMAT(1X,'INPUT CG LOCATION (FROM NOSE)')                        LAE02460
      READ 1070, XCG                                                    LAE02470
      IF(IABC.EQ.1)GO TO 1100                                           LAE02480
60036 WRITE (6,10360)                                                   LAE02490
10360 FORMAT( 1X,'INPUT  REFERENCE AREA')                               LAE02500
      READ 1070, AREA                                                   LAE02510
      IF(IABC.EQ.1)GO TO 1100                                           LAE02520
60037 WRITE (6,10370)                                                   LAE02530
10370 FORMAT(1X,'INPUT  REFERENCE LENGTH')                              LAE02540
      READ 1070, XREF                                                   LAE02550
      IF(IABC.EQ.1)GO TO 1100                                           LAE02560
60038 WRITE (6,10380)                                                   LAE02570
10380 FORMAT( 1X,'ENGINE CODE, 0.0=TURBOFAN, 1.0=ROCKET')               LAE02580
      READ 1070, ENGINE                                                 LAE02590
      IF(IABC.EQ.1)GO TO 1100                                           LAE02600
60039 WRITE (6,10390)                                                   LAE02610
10390 FORMAT(1X,'INLET CODE, 0.0=FLUSH, 1.0=EXTENDED')                  LAE02620
      READ 1070, ENLET                                                  LAE02630
      IF(IABC.EQ.1)GO TO 1100                                           LAE02640
60040 WRITE (6,10400)                                                   LAE02650
10400 FORMAT( 1X,'INPUT BOATTAIL ANGLE (DEGS)')                         LAE02660
      READ 1070, BETA                                                   LAE02670
      IF(IABC.EQ.1)GO TO 1100                                           LAE02680
60041 WRITE (6,10410)                                                   LAE02690
10410 FORMAT(1X,'INPUT BASE DIAMETER')                                  LAE02700
      READ 1070, DBASE                                                  LAE02710
      IF(IABC.EQ.1)GO TO 1100                                           LAE02720
60042 WRITE (6,10420)                                                   LAE02730
10420 FORMAT( 1X,'INPUT NOZZLE EXIT DIAMETER')                          LAE02740
      READ 1070,DJET                                                    LAE02750
      IF(IABC.EQ.1)GO TO 1100                                           LAE02760
60043 WRITE (6,10430)                                                   LAE02770
10430 FORMAT(1X,'INPUT BOATTAIL LENGTH')                                LAE02780
      READ 1070, XLABOD                                                 LAE02790
      IF(IABC.EQ.1)GO TO 1100                                           LAE02800
60044 WRITE (6,10440)                                                   LAE02810
10440 FORMAT( 1X,'INPUT PROTUBERANCE DRAG')                             LAE02820
      READ 1070,CDPROT                                                  LAE02830
      IF(IABC.EQ.1)GO TO 1100                                           LAE02840
C                                                                       LAE02850
 1100 REWIND 08                                                         LAE02860
      REWIND 07                                                         LAE02870
      CALL SCREEN                                                       LAE02880
 1110 WRITE (6,1130)                                                    LAE02890
      WRITE (6,1140) TITL1,TITL2,TITL3,TITL4,TITL5,TITL6,TITL7,TITL8,   LAE02900
     *TITL9,TITL0,TITL01,TITL02,TITL03,TITL04,TITL05                    LAE02910
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      WRITE (6,1120)                                                    LAE02920
 1120 FORMAT(1X,'BE SURE TO NOTE NUMBER OF ANY INCORRECT ENTRIES'//)    LAE02930
      WRITE (6,1150) ICSC,INOSE,IDT,IM,IAL,NBODY,ISWPW,IAFBW,ISWEPW,    LAE02940
     *NWING,ISWPT,IAFBT                                                 LAE02950
      WRITE (6,1160) ISWEPT,NTAIL,XLAMW,CLAMW,BW,CROOTW,SW,XMACW,       LAE02960
     *XWING,TOVCW,XLAMT,CLAMT,BT,CROOTT,ST                              LAE02970
      WRITE (6,1170) XMACT,XTAIL,TOVCT,HT,D,XL,XLNOSE,XCG,AREA,XREF,    LAE02980
     *ENGINE,ENLET,BETA,DBASE,DJET,XLABOD,CDPROT                        LAE02990
      WRITE (6,1180)(XVXM(I), I=1,24)                                   LAE03000
      WRITE (6,1190)(XDT(I), I=1,24)                                    LAE03010
      WRITE (6,1200)(XAL(I), I=1,24)                                    LAE03020
 1130 FORMAT(1X,'THE FOLLOWING TABLE CONTAINS THE INPUT DATA FOR'/)     LAE03030
 1140 FORMAT(1X,15A4//)                                                 LAE03040
 1150 FORMAT(1X,' 1) (ICSC) CONTROL CONSTANT; 1=TAIL, 2=WING, 3=CANARD:'LAE03050
     *,T63,I2/,                                                         LAE03060
     *1X,' 2) (INOSE) NOSE SHAPE; 1=ELLIPSE, 2=OGIVE, 3=CONE;',T63,I2/, LAE03070
     *1X,' 3) (IDT) NUMBER OF CONTROL DEFLECTIONS:',T63,I2/,            LAE03080
     *1X,' 4) (IM) NUMBER OF MACH NUMBERS:',T63,I2/,                    LAE03090
     *1X,' 5) (IAL) NUMBER OF ANGLES OF ATTACK:',T63,I2/,               LAE03100
     *1X,' 6) (NBODY) NUMBER OF CONFIGURATIONS:',T63,I2/,               LAE03110
     *1X,' 7) (ISWPW) 1=NON-DELTA WING, 2=DELTA WING:',T63,I2/,         LAE03120
     *1X,' 8) (IAFBW) 0=NO BODY AFTER WING, 1=BODY AFTER WING:',T63,I2/,LAE03130
     *1X,' 9) (ISWEPW) WING SWEEP CONSTANT (IF DELTA=0)'/,              LAE03140
     *15X,'0=UNSWEPT LEADING EDGE, 1=SWEPT LEADING EDGE:',T63,I2/,      LAE03150
     *1X,'10) (NWING) NUMBER OF WINGS:',T63,I2/,                        LAE03160
     *1X,'11) (ISWPT) 1=NON-DELTA TAIL, 2=DELTA TAIL:',T63,I2/,         LAE03170
     *1X,'12) (IAFBT) 0=NO BODY AFTER TAIL,1=BODY AFTER TAIL:',T63,I2)  LAE03180
 1160 FORMAT(1X,'13) (ISWEPT) TAIL SWEEP CONSTANT (IF DELTA=0)'/,       LAE03190
     *15X,'0=UNSWEPT LEADING EDGE, 1=SWEPT LEADING EDGE:',T63,I2/,      LAE03200
     *1X,'14) (NTAIL) NUMBER OF TAILS:',T63,I2/,                        LAE03210
     *1X,'15) (XLAMW) TIP-TO-CHORD RATIO OF WING:',T56,F12.3/,          LAE03220
     *1X,'16) (CLAMW) WING LEADING EDGE SWEEP(DEGREES):',T56,F12.3/,    LAE03230
     *1X,'17) (BW) WING SPAN, INCLUDING BODY:',T56,F12.3/,              LAE03240
     *1X,'18) (CROOTW) WING ROOT CHORD (AT BODY JUNCTION):',T56,F12.3/, LAE03250
     *1X,'19) (SW) EXPOSED WING AREA (TWO PANELS):',T56,F12.3/,         LAE03260
     *1X,'20) (XMACW) WING MEAN GEOMETRIC CHORD:',T56,F12.3/,           LAE03270
     *1X,'21) (XWING) DISTANCE FROM NOSE TO WING LE:',T56,F12.3/,       LAE03280
     *1X,'22) (TOVCW) WING THICKNESS TO CHORD RATIO:',T56,F12.3/,       LAE03290
     *1X,'23) (XLAMT) TIP-TO-CHORD RATIO OF TAIL:',T56,F12.3/,          LAE03300
     *1X,'24) (CLAMT) TAIL LEADING EDGE SWEEP (DEGREES):',T56,F12.3/,   LAE03310
     *1X,'25) (BT) TAIL SPAN, INCLUDING BODY:',T56,F12.3/,              LAE03320
     *1X,'26) (CROOTT) TAIL ROOT CHORD:',T56,F12.3/,                    LAE03330
     *1X,'27) (ST) EXPOSED TAIL AREA (TWO PANELS):',T56,F12.3)          LAE03340
 1170 FORMAT(1X,'28) (XMACT) TAIL MEAN GEOMETRIC CHORD:',T56,F12.3/,    LAE03350
     *1X,'29) (XTAIL) DISTANCE FROM NOSE TO TAIL LE:',T56,F12.3/,       LAE03360
     *1X,'30) (TOVCT) TAIL THICKNESS TO CHORD RATIO:',T56,F12.3/,       LAE03370
     *1X,'31) (HT) ALTITUDE:',T56,F12.3/,                               LAE03380
     *1X,'32) (D) BODY DIAMETER:',T56,F12.3/,                           LAE03390
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     *1X,'33) (XL) MISSILE LENGTH:',T56,F12.3/,                        LAE03400
     *1X,'34) (XLNOSE) NOSE LENGTH:',T56,F12.3/,                       LAE03410
     *1X,'35) (XCG) DISTANCE TO CG LOCATION FROM NOSE:',T56,F12.3/,    LAE03420
     *1X,'36) (AREA) REFERENCE AREA:',T56,F12.3/,                      LAE03430
     *1X,'37) (XREF) REFERENCE LENGTH:',T56,F12.3/,                    LAE03440
     *1X,'38) (ENGINE) ENGINE; 0.0=TURBOFAN, 1.0=ROCKET:',T63,F3.1/,   LAE03450
     *1X,'39) (ENLET) INLET; 0.0=FLUSH, 1.0=EXTENDED:',T63,F3.1/,      LAE03460
     *1X,'40) (BETA) BOAT-TAIL ANGLE (DEGREES):',T56,F12.3/,           LAE03470
     *1X,'41) (DBASE) BASE DIAMETER:',T56,F12.3/,                      LAE03480
     *1X,'42) (DJET) NOZZLE EXIT DIAMETER:',T56,F12.3/,                LAE03490
     *1X,'43) (XLABOD) BOAT-TAIL LENGTH:',T56,F12.3/,                  LAE03500
     *1X,'44) (CDPROT) PROTUBERANCE DRAG:',T56,F12.3//)                LAE03510
 1180 FORMAT(1X,'MACH ',12F6.3/,6X,12F6.3/)                             LAE03520
 1190 FORMAT(1X,'DELTA',12F6.2/,6X,12F6.2/)                             LAE03530
 1200 FORMAT(1X,'ALPHA',12F6.2/,6X,12F6.2/)                             LAE03540
C                                                                       LAE03550
      IABC=1                                                            LAE03560
      WRITE (6,1210)                                                    LAE03570
 1210 FORMAT(1X,'IS INPUT DATA CORRECT? 00=YES, IF NO,'/                LAE03580
     *1X,'ENTER THE TWO-DIGIT NUMBER OF THE VARIABLE TO BE CHANGED.')   LAE03590
      READ 1060, IVAR                                                   LAE03600
      IF(IVAR.EQ.0)GO TO 1220                                           LAE03610
      GO TO (60001,60002,60003,60004,60005,60006,60007,60008,60009,     LAE03620
     *60010,60011,60012,60013,60014,60015,60016,60017,60018,60019,      LAE03630
     *60020,60021,60022,60023,60024,60025,60026,60027,60028,60029,      LAE03640
     *60030,60031,60032,60033,60034,60035,60036,60037,60038,60039,      LAE03650
     *60040,60041,60042,60043,60044),IVAR                               LAE03660
 1220 CONTINUE                                                          LAE03670
      WRITE(8,1130)                                                     LAE03680
      WRITE(8,1140) TITL1,TITL2,TITL3,TITL4,TITL5,TITL6,TITL7,TITL8,TITLLAE03690
     *9,TITL0,TITL01,TITL02,TITL03,TITL04,TITL05                        LAE03700
      WRITE(8,1150) ICSC,INOSE,IDT,IM,IAL,NBODY,ISWPW,IAFBW,ISWEPW,     LAE03710
     *NWING,ISWPT,IAFBT                                                 LAE03720
      WRITE(8,1160) ISWEPT,NTAIL,XLAMW,CLAMW,BW,CROOTW,SW,XMACW,        LAE03730
     *XWING,TOVCW,XLAMT,CLAMT,BT,CROOTT,ST                              LAE03740
      WRITE(8,1170) XMACT,XTAIL,TOVCT,HT,D,XL,XLNOSE,XCG,AREA,XREF,     LAE03750
     *ENGINE,ENLET,BETA,DBASE,DJET,XLABOD,CDPROT                        LAE03760
      WRITE(8,1180)(XVXM(I), I=1,24)                                    LAE03770
      WRITE(8,1190)(XDT(I), I=1,24)                                     LAE03780
      WRITE(8,1200)(XAL(I), I=1,24)                                     LAE03790
 1230 PIE=3.14159                                                       LAE03800
       IL = 1 + IL                                                      LAE03810
      LLKK=0                                                            LAE03820
      LLLL=0                                                            LAE03830
       XCG2 = XCG                                                       LAE03840
       IZZY = 0                                                         LAE03850
      IF(INOSE.EQ.3)GO TO 1250                                          LAE03860
      IF(INOSE.EQ.2)GO TO 1240                                          LAE03870
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      XC=XL/2.                                                          LAE03880
      AP=XL*D                                                           LAE03890
      GO TO 1260                                                        LAE03900
 1240 XLNOD=XLNOSE/D                                                    LAE03910
      RADIUS=XLNOD**2+.25                                               LAE03920
      APOD2=XLNOD*SQRT(RADIUS**2-XLNOD**2)+RADIUS**2                    LAE03930
     **ARSIN(XLNOD/RADIUS)-2.*XLNOD*(RADIUS-.5)                         LAE03940
      APN=APOD2*D*D                                                     LAE03950
      AP=(XL-XLNOSE)*D+APN                                              LAE03960
      XCOD1=RADIUS**3-(RADIUS**2-XLNOD**2)**1.5                         LAE03970
      XCOD=XLNOD-(.6667*XCOD1-XLNOD**2*(RADIUS-.5))/APOD2               LAE03980
      XCMOVE=XCOD*D-XLNOSE/2.                                           LAE03990
      XC=XL/2.+XCMOVE                                                   LAE04000
      GO TO 1260                                                        LAE04010
 1250 APN=.5*D*XLNOSE                                                   LAE04020
      AP=APN+(XL-XLNOSE)*D                                              LAE04030
      XCN=.6667*XLNOSE                                                  LAE04040
      XCMOVE=XCN-XLNOSE/2.                                              LAE04050
      XC=XL/2.+XCMOVE                                                   LAE04060
 1260 CONTINUE                                                          LAE04070
      CALL GEOSUB                                                       LAE04080
 1270 CONTINUE                                                          LAE04090
      CALL SCREEN                                                       LAE04100
      VXM=XVXM(1)                                                       LAE04110
C     RE=REFT*VXM                                                       LAE04120
      RE=REFTI                                                          LAE04130
      SQ=2.                                                             LAE04140
      DO 3590 IJ=1,IM                                                   LAE04150
      REFT=REFTI/VXM                                                    LAE04160
      DELTA1=XDT(1)                                                     LAE04170
      DO 3580 II=1,IDT                                                  LAE04180
      ALPHA=XAL(1)                                                      LAE04190
      WRITE (6,1280) VXM                                                LAE04200
C                                                                       LAE04210
 1280 FORMAT(//,1X,'MACH ',F7.4)                                        LAE04220
      WRITE (6,1290) DELTA1                                             LAE04230
 1290 FORMAT(1X,'DELTA=',F6.2)                                          LAE04240
      WRITE (6,1300)                                                    LAE04250
 1300 FORMAT(1X,'AL',3X,'CLTOT',2X,'CDTCT',3X,'CLWP',3X,'CLBW',3X,'CLTP'LAE04260
     *,3X,'CLBT',4X,'CLB',4X,'CDI',3X,'CNWP',3X,'CNTP')                 LAE04270
      WRITE (6,1310)                                                    LAE04280
 1310 FORMAT(7X,'CLTD',3X,'CDTD',5X,'CN',5X,'CA',3X,'XCPW',3X,'XCPT',3X,LAE04290
     *'XCPB',4X,'XCP',5X,'CM')                                          LAE04300
      WRITE(8,1280) VXM                                                 LAE04310
      WRITE(8,1290) DELTA1                                              LAE04320
      WRITE(8,1320)                                                     LAE04330
 1320 FORMAT(1X,'AL',2X,'CLTOT',1X,'CDTCT',2X,'CLWP',2X,'CLBW',2X,'CLTP'LAE04340
     *,2X,'CLBT',3X,'CLB',3X,'CDI',2X,'CNWP',2X,'CNTP',2X,'CLTD',2X,    LAE04350
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     *'CDTD',4X,'CN',4X,'CA',2X,'XCPW',2X,'XCPT',2X,'XCPB',3X,'XCP',4X, LAE04360
     *'CM',/)                                                           LAE04370
C                                                                       LAE04380
 1330 DELTA=DELTA1/57.29578+.000000001                                   LAE04390
      DO 3540 J=1,IAL                                                   LAE04400
      AL=ALPHA/57.29578+.00000001                                       LAE04410
      SINAAL=SIN(AL)                                                    LAE04420
      COSAAL=COS(AL)                                                    LAE04430
    1 VXMR1=VXM                                                         LAE04440
      IZZY=IZZY+1                                                       LAE04450
      IF (IZZY -4) 1340,1340,1350                                       LAE04460
 1340 VXM=.6                                                            LAE04470
 1350 CALL CLASUB                                                       LAE04480
      IF(LLLL-1) 1360,1640,1710                                         LAE04490
 1360 IF(IZZY-4) 1380,1380,1370                                         LAE04500
 1370 CALL CATSUB                                                       LAE04510
 1380 XLAM14=ATAN((.5*(B1-D)*1./COLAM+.25*XLAM1*CROOT-.25*CROOT)/        LAE04520
     *(.5*(B1-D)))                                                      LAE04530
      RE=REFT*VXM*XMAC                                                  LAE04540
      IF (RE-1.E06) 1390,1400,1400                                      LAE04550
 1390 AA=.0835                                                          LAE04560
      XNN=-.211                                                         LAE04570
       GO TO 1450                                                       LAE04580
 1400 IF (RE-1.E07) 1410,1420,1420                                      LAE04590
 1410 AA=.052                                                           LAE04600
      XNN=-.177                                                         LAE04610
       GO TO 1450                                                       LAE04620
 1420 IF (RE-1.E08) 1430,1440,1440                                      LAE04630
 1430 AA=.0333                                                          LAE04640
      XNN=-.1488                                                        LAE04650
      GO TO 1450                                                        LAE04660
 1440 AA=.0221                                                          LAE04670
      XNN=-.127                                                         LAE04680
 1450 CF=AA*RE**XNN                                                     LAE04690
      SURF=FLOAT(NSURF)                                                 LAE04700
      CDO=SURF*CF*(1.+2.*TOVC+100.*TOVC**4.)                            LAE04710
      IF (IZZY-4) 1460,1460,1470                                        LAE04720
 1460 IF (IZZY-3) 1580,1630,1670                                        LAE04730
 1470 IF (AL)  1480,1490,1490                                           LAE04740
 1480 ODC=-ODC                                                          LAE04750
 1490 LLKK=LLKK+1                                                       LAE04760
      IF (LLKK-2) 1500,1520,1540                                        LAE04770
 1500 IF (SW) 1510,1510,1540                                            LAE04780
 1510 LLKK=LLKK+1                                                       LAE04790
 1520 IF (SW2) 1530,1530,1540                                           LAE04800
 1530 LLKK=LLKK+1                                                       LAE04810
 1540 IF (LLKK-2) 1550,1600,1660                                        LAE04820
 1550 XKWBW=XKWB                                                        LAE04830
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      XKBWW=XKBW                                                        LAE04840
      IF(ISWEPW.EQ.0) GO TO 1560                                        LAE04850
      SHIFT=TAN(CLAMW)*(BW-D)/4.0                                       LAE04860
      GO TO 1570                                                        LAE04870
 1560 SHIFT=0.0                                                         LAE04880
 1570 XCPWB=XWING+XBCRWB*CROOT+SHIFT                                    LAE04890
      XCPBW=XWING+XBCRBW*CROOT                                          LAE04900
      ODCW=ODC                                                          LAE04910
      CLW=SIN(AL)*(XKWBW+XKBWW)*CLALW*SW*COS(AL)/AREA                   LAE04920
      CLWB=SIN(AL)*XKWBW*CLALW*SW*COS(AL)/AREA                          LAE04930
      CLBW=CLW-CLWB                                                     LAE04940
      CLVISW=    (SIN(AL)*SIN(AL)*SW*COS(AL)/AREA)*ODCW                 LAE04950
      CLW=CLW+CLVISW                                                    LAE04960
      CLWP=CLWB+CLVISW                                                  LAE04970
 1580 CDOW=CDO*(SW)/AREA                                                LAE04980
      XLAMW4=XLAM14                                                     LAE04990
      TOVCW=TOVC                                                        LAE05000
      SWTOT=SW                                                          LAE05010
      IZZY=IZZY+1                                                       LAE05020
      IF(SW2) 1640,1640,1590                                            LAE05030
 1590 COLAM=COS(CLAMW2)/SIN(CLAMW2)                                     LAE05040
      CDOW2=0.                                                          LAE05050
      BCOLAM=BETA1*COLAM                                                LAE05060
      CROOT=CROOW2                                                      LAE05070
      B1=BW2                                                            LAE05080
      IAFB=IAFBW2                                                       LAE05090
      CLAL1=CLALW2                                                      LAE05100
      XLAM1=XLAMW2                                                      LAE05110
      TOVC=TOVCW2                                                       LAE05120
      XMAC=XMACW2                                                       LAE05130
      ISWP1=ISWPW2                                                      LAE05140
      BAR=BETA1*ARW2                                                    LAE05150
      RATIO=CROOT/(BETA1*D)                                             LAE05160
      IF(IZZY-4) 1380,1380,1370                                         LAE05170
 1600 XKWBW2=XKWB                                                       LAE05180
      XKBWW2=XKBW                                                       LAE05190
      IF(ISWEP2.EQ.0) GO TO 1610                                        LAE05200
      SHIFT=TAN(CLAMW2)*(BW2-D)/4.0                                     LAE05210
      GO TO 1620                                                        LAE05220
 1610 SHIFT=0.                                                          LAE05230
 1620 XCPWB2=XWING2+XBCRWB*CROOT+SHIFT                                  LAE05240
      XCPBW2=XWING2+XBCRBW*CROOT                                        LAE05250
      ODCW2=ODC                                                         LAE05260
      CLW2=SIN(AL)*(XKWBW2+XKBWW2)*CLALW2*SW2*COS(AL)/AREA              LAE05270
      CLWB2=SIN(AL)*XKWBW2*CLALW2*SW2*COS(AL)/AREA                      LAE05280
      CLBW2=CLW2-CLWB2                                                  LAE05290
      CLVIW2=(SIN(AL)*SIN(AL)*SW2*COS(AL)/AREA)*ODCW2                   LAE05300
      CLW2=CLW2+CLVIW2                                                  LAE05310
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1630 CDOW2=CDO*(SW2)/AREA                                               LAE05320
     XLAM24=XLAM14                                                      LAE05330
     SW2TOT=SW2                                                         LAE05340
1640 IZZY =  IZZY +1                                                    LAE05350
     LLKK=LLKK+2                                                        LAE05360
     IF (ST) 1710,1710,1650                                             LAE05370
1650 COLAM=COS(CLAMT)/SIN(CLAMT)                                        LAE05380
     ART=(BT-D)**2/ST                                                   LAE05390
     BCOLAM=BETA1*COLAM                                                 LAE05400
     CROOT=CROOTT                                                       LAE05410
     B1=BT                                                              LAE05420
     BAR=BETA1*ART                                                      LAE05430
     CLAL1=CLALT                                                        LAE05440
     IAFB=IAFBT                                                         LAE05450
     XMAC=XMACT                                                         LAE05460
     TOVC=TOVCT                                                         LAE05470
     ISWP1=ISWPT                                                        LAE05480
     XLAM1=XLAMT                                                        LAE05490
     RATIO=CROOT/(BETA1*D)                                              LAE05500
     IF (IZZY-4) 1380,1380,1370                                         LAE05510
1660 XKWBT=XKWB                                                         LAE05520
     XKBWT=XKBW                                                         LAE05530
     XCPBT=XTAIL+XBCRBW*CROOT                                           LAE05540
     ODCT=ODC                                                           LAE05550
     CLT=((XKWBT+XKBWT)*SIN(AL))*CLALT*ST*COS(AL)/AREA                  LAE05560
     CLTB=SIN(AL)*XKWBT*CLALT*ST*COS(AL)/AREA                           LAE05570
     CLBT=CLT-CLTB                                                      LAE05580
     CLTD=XKTB*CLALT*SIN(DELTA)*ST*COS(AL+DELTA)/AREA                   LAE05590
     CLTDB=(XKTB+XKBT)*CLALT*SIN(DELTA)*ST*COS(AL+DELTA)/AREA           LAE05600
     CLBDT=CLTDB-CLTD                                                   LAE05610
     CLBT=CLBT+CLBDT                                                    LAE05620
     CLVIST=((SIN(AL+DELTA)*SIN(AL+DELTA))*ST*COS(AL+DELTA)/AREA)*ODCT  LAE05630
     CLT=CLT+CLVIST                                                     LAE05640
     CLTP=CLTB+CLVIST+CLTD                                              LAE05650
1670 CDOT=CDO*(ST)/AREA                                                 LAE05660
     CT=CDOT                                                            LAE05670
     STTOT=ST                                                           LAE05680
     XLAMT4=XLAM14                                                      LAE05690
     IF (IZZY-4) 1900,1900,1680                                         LAE05700
1680 IF(ISWEPT.EQ.0) GO TO 1690                                         LAE05710
     SHIFT=TAN(CLAMT)*(BT-D)/4.0                                        LAE05720
     GO TO 1700                                                         LAE05730
1690 SHIFT=0.0                                                          LAE05740
1700 XCPTB=XTAIL+((XKWBT*SIN(AL)*XBCRWB+XKTB*SIN(DELTA)*XBCRWB)/        LAE05750
    *(XKWBT*SIN(AL)+XKTB*SIN(DELTA)))*CROOTT+SHIFT                      LAE05760
1710  IF (IZZY - 4) 1900, 1900, 1720                                    LAE05770
1720  XLOB = XL/D                                                       LAE05780
     ZXM=VXM*ABS(SIN(AL))                                               LAE05790
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      IF (ZXM-.8) 1730,1740,1740                                        LAE05800
 1730 CDC=2.4-SQRT(1.5129-1.5129*ZXM*ZXM)                               LAE05810
      GO TO 1790                                                        LAE05820
 1740 IF (ZXM-1.15) 1750,1760,1760                                      LAE05830
 1750 CDC=1.6+SQRT(.344-(ZXM-.975)**2)                                  LAE05840
      GO TO 1790                                                        LAE05850
 1760 IF (ZXM-3.) 1770,1780,1780                                        LAE05860
 1770 CDC=1.9-SQRT(.361-.09*(ZXM-3.)**2)                                LAE05870
      GO TO 1790                                                        LAE05880
 1780 CDC=1.3                                                           LAE05890
                                                                        LAE05900
 1790 ETA=(0.0000475*(XLOB**3))-(0.00173*(XLOB**2))+(0.0298*XLOB)+0.5146LAE05910
      IF (VXM-.5) 1830,1830,1800                                        LAE05920
 1800 IF (VXM-1.4) 1810,1820,1820                                       LAE05930
 1810 ETA=ETA+(1.-ETA)*(VXM-.5)*1.111                                   LAE05940
      GO TO 1830                                                        LAE05950
 1820 ETA=1.                                                            LAE05960
 1830 IF (XLOB-10.) 1840,1850,1860                                      LAE05970
 1840 XK2K1=-0.0054*(XLOB**2)+0.104*XLOB+0.437                          LAE05980
      GO TO 1870                                                        LAE05990
 1850 XK2K1=0.939                                                       LAE06000
      GO TO 1870                                                        LAE06010
 1860 XK2K1=0.939+(0.001525*(XLOB-10.0))                                LAE06020
 1870 ALP=AL                                                            LAE06030
      IF(AL) 1880,1890,1890                                             LAE06040
 1880 CDC=-CDC                                                          LAE06050
 1890 CNB=(XK2K1*SIN(2.*ALP)*COS(ALP/2.))*3.14159*D*D/(4.*AREA)         LAE06060
     *+ETA*CDC*((AP   )/AREA)*((SIN(ALP))**2)                          LAE06070
      XQ=XCG/D                                                          LAE06080
      CMB1=(XK2K1*XQ*SIN(2.*ALP)*COS(ALP/2.))*3.14159*D*D*D/            LAE06090
     *(4.*AREA*XREF)                                                    LAE06100
      CMB2=(ETA*CDC*((AP   )/AREA)*((XCG-(XC   ))/D)*((SIN(ALP)**2)))   LAE06110
     **D/XREF                                                           LAE06120
      CMB=CMB1+CMB2                                                     LAE06130
 1900 RE=REFT*VXM*XL                                                    LAE06140
      IF (RE-1.E06) 1910,1920,1920                                      LAE06150
 1910 AA=.0835                                                          LAE06160
      XNN=-.211                                                         LAE06170
      GO TO 1970                                                        LAE06180
 1920 IF (RE-1.E07) 1930,1940,1940                                      LAE06190
 1930 AA=.052                                                           LAE06200
      XNN=-.177                                                         LAE06210
      GO TO 1970                                                        LAE06220
 1940 IF (RE-1.E08) 1950,1960,1960                                      LAE06230
 1950 AA=.033                                                           LAE06240
      XNN=-.1488                                                        LAE06250
      GO TO 1970                                                        LAE06260
 1960 AA=.0221                                                          LAE06270
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      XNN=-.127                                                         LAE06280
 1970 CFBOD=AA*RE**XNN                                                  LAE06290
      CDOB=(1.02*CFBOD*(1.0+.0025*XLOB+60.0/(XLOB**3.0))*SSUBS/AREA)    LAE06300
     *+CDPROT                                                           LAE06310
      IF(ENGINE.EQ.1.0) GO TO 1990                                      LAE06320
      IF(ENLET.EQ.1.0) GO TO 1980                                       LAE06330
      CDINL=.038*CDOB                                                   LAE06340
      GO TO 2000                                                        LAE06350
 1980 CDINL=0.05*CDOB                                                   LAE06360
      GO TO 2000                                                        LAE06370
 1990 CDINL=.0                                                          LAE06380
C   BASE DRAG (NO BOATTAIL)                                             LAE06390
 2000 CBPRI=-(((((2.8*VXM-.4)/2.4)/VXM**2.28)*.8123)-1.)*1.4286/VXM**2. LAE06400
      SB=(DBASE-DJET)*(DBASE+DJET)*3.14159/4.                           LAE06410
      CB=CBPRI*SB/AREA                                                  LAE06420
      IF (CB.LT.0.0) CB=0.0                                             LAE06430
      IF (BETA.NE.0.0) CB=0.0                                           LAE06440
      CDOB=CDOB+CB                                                      LAE06450
C   AFTERBODY DRAG CALCULATIONS (BOATTAIL)                              LAE06460
      DELCPO=0.                                                         LAE06470
      DELCPD=0.                                                         LAE06480
      DRATIO=(DBASE**2-DJET**2)/(D**2)                                  LAE06490
      DRATO1=(DJET**2)/(DBASE*D)                                        LAE06500
      DBDM=DBASE/D                                                      LAE06510
      DELBAS=-.1532+(.0247*BETA1)-(.002632*(BETA1**2))                  LAE06520
      CPBSO1=-.11905+(.00017*DBDM)-(.0283*(DBDM**2))                    LAE06530
      CPBSO2=-.0273+(.00425*DBDM)-(.1143*(DBDM**2))                     LAE06540
      CPBSO3=-.0612+(.3485*DBDM)-(.4254*(DBDM**2))                      LAE06550
      CPBSO4=.0789+(.5252*DBDM)-(.7434*(DBDM**2))                       LAE06560
      CPBSO5=-.085+(1.324*DBDM)-(1.407*(DBDM**2))                       LAE06570
      IF(BETA-3.0)2010,2010,2020                                        LAE06580
 2010 CPBSO=((CPBSO1+0.15)*BETA/3.0)-.15                                LAE06590
      GO TO 2090                                                        LAE06600
 2020 IF(BETA-5.6)2030,2030,2040                                        LAE06610
 2030 CPBSO=((CPBSO2-CPBSO2)*(BETA-3.0)/2.6)+CPBSO1                     LAE06620
      GO TO 2090                                                        LAE06630
 2040 IF(BETA-8.0)2050,2050,2060                                        LAE06640
 2050 CPBSO=((CPBSO3-CPBSO2)*(BETA-5.6)/2.4)+CPBSO2                     LAE06650
      GO TO 2090                                                        LAE06660
 2060 IF(BETA-16.0)2070,2070,2080                                       LAE06670
 2070 CPBSO=((CPBSO4-CPBSO3)*(BETA-8.0)/8.0)+CPBSO3                     LAE06680
      GO TO 2090                                                        LAE06690
 2080 CPBSO=((CPBSO5-CPBSO4)*(BETA-16.0)/4.0)+CPBSO4                    LAE06700
 2090 CDBASE=(-DRATIO)*(CPBSO+DELCPO+(DELCPO*DRATO1))                   LAE06710
      IF(ENGINE.EQ.1.0)GO TO 2470                                       LAE06720
      IF(DBDM-.76)2100,2100,2110                                        LAE06730
 2100 CBOAT5=.1013*DBDM                                                 LAE06740
      GO TO 2130                                                        LAE06750
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2110 IF(DBDM.LT.0.82) GO TO 2120                                    LAE06760
     CBOAT5=-.4*(DBDM-.82)+.077                                     LAE06770
     GO TO 2130                                                     LAE06780
2120 CBOAT5=.077                                                    LAE06790
2130 IF(DBDM-.245)2140,2140,2150                                    LAE06800
2140 CBOAT4=.0653*DBDM                                              LAE06810
     GO TO 2180                                                     LAE06820
2150 IF(DBDM.GT.0.76) GO TO 2160                                    LAE06830
     CBOAT4=.1048*(DBDM-.245)+.016                                  LAE06840
     GO TO 2180                                                     LAE06850
2160 IF(DBDM.GT.0.82) GO TO 2170                                    LAE06860
     CBOAT4=.071                                                    LAE06870
     GO TO 2180                                                     LAE06880
2170 CBOAT4=-.369*(DBDM-.82)+.07                                    LAE06890
2180 IF(DBDM-.36)2190,2190,2200                                     LAE06900
2190 CBOAT3=.0292*DBDM                                              LAE06910
     GO TO 2230                                                     LAE06920
2200 IF(DBDM.GT.0.76) GO TO 2210                                    LAE06930
     CDOAT3=.10125*(DBDM-.36)+.0105                                 LAE06940
     GO TO 2230                                                     LAE06950
2210 IF(DBDM.GT.0.81) GO TO 2220                                    LAE06960
     CBOAT3=.057                                                    LAE06970
     GO TO 2230                                                     LAE06980
2220 CBOAT3=-.2579*(DBDM-.81)+.051                                  LAE06990
2230 IF(DBDM-.32)2240,2240,2250                                     LAE07000
2240 CBOAT2=.0125*DBDM                                              LAE07010
     GO TO 2290                                                     LAE07020
2250 IF(DBDM.GT.0.5) GO TO 2260                                     LAE07030
     CBOAT2=.0333*(DBDM-.32)+.004                                   LAE07040
     GO TO 2290                                                     LAE07050
2260 IF(DBDM.GT.0.72) GO TO 2270                                    LAE07060
     CBOAT2=.1068*(DBDM-.5)+.01                                     LAE07070
     GO TO 2290                                                     LAE07080
2270 IF(DBDM.GT.0.76) GO TO 2280                                    LAE07090
     CBOAT2=.0335                                                   LAE07100
     GO TO 2290                                                     LAE07110
2280 CBOAT2=-.1354*(DBDM-.76)+.0335                                 LAE07120
2290 IF(DBDM-.6)2300,2300,2310                                      LAE07130
2300 CBOAT1=.0055-(.03375*DBDM)+(.06875*(DBDM**2))                  LAE07140
     GC TO 2340                                                     LAE07150
2310 IF(DBDM.GT.0.75) GO TO 2320                                    LAE07160
     CBOAT1=.1*(DBDM-.6)+.01                                        LAE07170
     GO TO 2340                                                     LAE07180
2320 IF(DBDM.GT.0.78) GO TO 2330                                    LAE07190
     CBOAT1=.025                                                    LAE07200
     GO TO 2340                                                     LAE07210
2330 CBOAT1=-.091*(DBDM-.78)+.025                                   LAE07220
2340 IF(BETA-3.0)2350,2350,2360                                     LAE07230
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2350 CBOAT1=(CBOAT1*BETA)/3.0                                           LAE07240
     GO TO 2460                                                         LAE07250
2360 IF(BETA-5.6)2370,2370,2380                                         LAE07260
2370 CBOAT1=((CBOAT2-CBOAT1)*(BETA-3.0)/2.6)+CBOAT1                     LAE07270
     GO TO 2460                                                         LAE07280
2380 IF(BETA-8.0)2390,2390,2400                                         LAE07290
2390 CBOAT1=((CBOAT3-CBOAT2)*(BETA-5.6)/2.4)+CBOAT2                     LAE07300
     GO TO 2460                                                         LAE07310
2400 IF(BETA-16.0)2410,2410,2420                                        LAE07320
2410 CBOAT1=((CBOAT4-CBOAT3)*(BETA-8.0)/8.0)+CBOAT3                     LAE07330
     GO TO 2460                                                         LAE07340
2420 IF(BETA-24.0)2430,2430,2440                                        LAE07350
2430 CBOAT1=((CBOAT5-CBOAT4)*(BETA-16.0)/8.0)+CBOAT4                    LAE07360
     GO TO 2460                                                         LAE07370
2440 PRINT 2450                                                         LAE07380
2450 FORMAT(1X,'BOATTAIL ANGLE GREATER THAN 24 DEGREES')                LAE07390
     CBOAT1=CBOAT5                                                      LAE07400
2460 CDBOAT=CBOAT1+DELBAS*(DELCPO+(DELCPD)*(DRATO1))                    LAE07410
     CDAFT=CDBOAT+CDBASE                                                LAE07420
2470 FR=XLNOSE/D                                                        LAE07430
     CDWN1=0.000407*(FR**8.0)-.0102*(FR**7.0)+.108*(FR**6.0)-.616*(     LAE07440
    *FR**5.)+2.074*(FR**4.0)-4.183*(FR**3.0)+4.891*(FR**2.0)-3.017*     LAE07450
    *FR+.7795                                                           LAE07460
      IF(FR.GT.1.0) CDWN1=.7432093E-04*FR**5.0-.15368398E-02*FR**4.0    LAE07470
    *+.011741209*FR**3.0-0.039555503*FR**2.0+0.050635882*FR+.005431397 LAE07480
     CDPTR=(CDWN1/.8)*VXM                                               LAE07490
     CDOB1=CDOB                                                         LAE07500
     CDOB=CDOB+CDINL+CDAFT+CDPTR                                        LAE07510
     CDOWBT=CDOW+CDOW2+CDOT+CDOB                                        LAE07520
     CDMISC=CDOWBT*.1                                                   LAE07530
     CDOWBT=CDOWBT+CDMISC                                               LAE07540
     IF (IZZY-4) 2480,2480,2550                                         LAE07550
2480 VXM=1.1999999                                                      LAE07560
     IF (SW) 2490,2490,2500                                             LAE07570
2490 CDOW=0.                                                            LAE07580
2500 IF (SW2) 2510,2510,2520                                            LAE07590
2510 CDOW2=0.                                                           LAE07600
2520 IF (ST) 2530,2530,2540                                             LAE07610
2530 CDOT=0.                                                            LAE07620
2540 HONST=CDOWBT                                                       LAE07630
     GO TO 2560                                                         LAE07640
2550 IF (VXM-1.2) 2560,2560,3020                                        LAE07650
2560  IF (SW) 2570,2570,2580                                            LAE07660
2570  DCDOSW = 0.0                                                      LAE07670
      SWTOT=0.0                                                         LAE07680
      CDOW = 0.0                                                        LAE07690
      GO TO 2740                                                        LAE07700
2580  XXM = VXM*SQRT(COS(XLAMW4))                                       LAE07710
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      SQMITC=SQRT(ABS((XXM*XXM)-1.0))/(TOVCW**0.33333)                  LAE07720
      ATC=ARW*(TOVCW**.333333)                                          LAE07730
      IZT=1                                                             LAE07740
 2590 IF (ATC-1.5) 2630,2600,2600                                       LAE07750
 2600 IF (VXM-1.) 2610,2610,2620                                        LAE07760
 2610 FUNCT=3.3081-1.88779*SQMITC+11.0916*SQMITC*SQMITC-18.6087*        LAE07770
     *SQMITC**3+7.4633*SQMITC**4                                        LAE07780
      FUNCT=FUNCT+(ATC-2.0)*0.1                                         LAE07790
      GO TO 2720                                                        LAE07800
 2620 FUNCT=3.0+(ATC-1.5)*0.3                                           LAE07810
      GO TO 2720                                                        LAE07820
 2630 IF (ATC-.5) 2690,2690,2640                                        LAE07830
 2640 IF (VXM-1.) 2650,2650,2680                                        LAE07840
 2650 FUNCT=2.47917-1.42798*SQMITC-.324405*SQMITC*SQMITC                LAE07850
      IF(SQMITC-0.4)2660,2670,2670                                      LAE07860
 2660 FUNCT=FUNCT+(1.8*(ATC-1.0))                                       LAE07870
 2670 FUNCT=FUNCT+(0.72*(ATC-1.0))/SQMITC                               LAE07880
      GO TO 2720                                                        LAE07890
 2680 FUNCT=(0.25*SQMITC)+(ATC*2.3)                                     LAE07900
      GO TO 2720                                                        LAE07910
 2690 IF (VXM-1.) 2700,2700,2710                                        LAE07920
 2700 FUNCT=0.9-(0.7*SQMITC)                                            LAE07930
      GO TO 2720                                                        LAE07940
 2710 FUNCT=.333*SQMITC+ATC*1.8                                         LAE07950
 2720 IF (IZT-2) 2730,2770,2810                                         LAE07960
 2730 DCDOSW=FUNCT*(TOVCW**1.66667)*((COS(XLAMW4))**2.5)                LAE07970
      IF(SQMITC.GT.1.3)DCDOSW=0.0                                       LAE07980
      IF(DCDOSW.LT.0.0)DCDOSW=0.0                                       LAE07990
      DCDOW=DCDOSW                                                      LAE08000
 2740  IF (SW2) 2750,2750,2760                                          LAE08010
 2750  DCDOS2 = 0.0                                                     LAE08020
       SW2TOT = 0.0                                                     LAE08030
       CDOW2= 0.0                                                       LAE08040
       GO TO 2780                                                       LAE08050
 2760  IZT = 2                                                          LAE08060
      XXM=VXM*SQRT(COS(XLAM24))                                         LAE08070
      SQMITC=SQRT(ABS((XXM*XXM)-1.))/(TOVCW2**0.33333)                  LAE08080
      ATC=ARW2*(TOVCW2**.33333)                                         LAE08090
      GO TO 2590                                                        LAE08100
 2770 DCDOS2=FUNCT*(TOVCW2**1.66667)*((COS(XLAM24))**2.5)               LAE08110
      IF(SQMITC.GT.1.3)DCDOS2=0.0                                       LAE08120
      IF(DCDOS2.LT.0.0)DCDOS2=0.0                                       LAE08130
      DCDOW2=DCDOS2                                                     LAE08140
 2780  IF (ST ) 2790,2790,2800                                          LAE08150
 2790  DCDOST = 0.0                                                     LAE08160
      STTOT=0.0                                                         LAE08170
       CDOT = 0.0                                                       LAE08180
       GO TO 2820                                                       LAE08190
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 2800  IZT = 3                                                          LAE08200
      XXM=VXM*SQRT(COS(XLAMT4))                                         LAE08210
      SQMITC=SQRT(ABS((XXM*XXM)-1.0))/(TOVCT**0.33333)                  LAE08220
      ATC=ART*(TOVCT**.33333)                                           LAE08230
      GO TO 2590                                                        LAE08240
 2810 DCDOST=FUNCT*(TOVCT**1.66667)*((COS(XLAMT4))**2.5)                LAE08250
      IF(SQMITC.GT.1.3)DCDOST=0.0                                       LAE08260
      IF(DCDOST.LT.0.0)DCDOST=0.0                                       LAE08270
      DCDOT=DCDOST                                                      LAE08280
 2820 IF(VXM-1.0)2840,2840,2830                                         LAE08290
 2830 IF(VXM-2.0)2850,2860,2860                                         LAE08300
C  TRANSONIC BODY DRAG                                                  LAE08310
 2840 COVC=1.0-(0.08*VXM)                                               LAE08320
      GO TO 2870                                                        LAE08330
 2850 COVC=0.92-(0.12*(VXM-1.0))                                        LAE08340
      GO TO 2870                                                        LAE08350
 2860  COVC =  1.31213-0.36633*VXM+.06038*VXM**2-.00601*VXM**3+.000275* LAE08360
     *VXM**4                                                            LAE08370
 2870 CDFPTR=1.02*CFBOD*COVC*SSUBS/AREA                                 LAE08380
        CDPPTR=CDOB1-1.02*CFBOD*SSUBS/AREA                              LAE08390
      IF(VXM-1.0) 2890,2890,2880                                        LAE08400
 2880 CDPPTR=(CDPPTR/0.2)*(1.2-VXM)                                     LAE08410
 2890 IF(FR.GT.2.0) GO TO 2900                                          LAE08420
      CDWN2=0.000172*(FR**8)-0.00453*(FR**7)+0.050*(FR**6)-0.304*(FR**5)LAE08430
     *+1.096*(FR**4)-2.406*(FR**3)+3.160*(FR**2)-2.391*(FR)+1.00        LAE08440
      CDWN3=.000125*(FR**8)-.00370*(FR**7)+.0447*(FR**6)-.288*(FR**5)   LAE08450
     *+1.076*(FR**4)-2.385*(FR**3)+3.141*(FR**2)-2.529*FR+1.300         LAE08460
      GO TO 2910                                                        LAE08470
 2900 CDWN2=-.33793095E-03*FR**5.0+.76402056E-02*FR**4.0-.67397615E-01* LAE08480
     *FR**3.0+.29429971*FR**2.0-.65782772*FR+.65397474                  LAE08490
      CDWN3=-.36714382E-03*FR**5.0+.88164977E-02*FR**4.0-.83661489E-01* LAE08500
     *FR**3.0+.39748005*FR**2.0-.9686696*FR+1.0327385                   LAE08510
 2910 IF(VXM-.8) 3000,2920,2930                                         LAE08520
 2920 CDPTR=CDWN1                                                       LAE08530
      GO TO 3000                                                        LAE08540
 2930 IF(VXM-1.0) 2950,2940,2960                                        LAE08550
 2940 CDPTR=CDWN2                                                       LAE08560
      GO TO 3000                                                        LAE08570
 2950 CDPTR=((CDWN2-CDWN1)/0.2)*(VXM-0.8)+CDWN1                         LAE08580
      GO TO 3000                                                        LAE08590
 2960 IF(VXM-1.2) 2980,2970,2990                                        LAE08600
 2970 CDPTR=CDWN3                                                       LAE08610
      GO TO 3000                                                        LAE08620
 2980 CDPTR=((CDWN3-CDWN2)/0.2)*(VXM-1.0)+CDWN2                         LAE08630
      GO TO 3000                                                        LAE08640
 2990 CDPTR=0.0                                                         LAE08650
 3000 CDOB=CB+CDFPTR+CDPPTR+CDINL+CDAFT+CDPTR                           LAE08660
C THE FOLLOWING INDENTED PROCEDURE WAS INSERTED TO FORCE THE CDOB        LAE08670
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C CURVE TO SMOOTHLY DECAY.  THE ORIGINAL PROGRAM DOES NOT CAUSE         LAE08680
C THE DRAG CURVE TO DECAY PROPERLY.                                     LAE08690
               IF (VXM.LE.1.0) F=0.0                                    LAE08700
               IF (VXM.GT.1.0) F=48.3841618-106.7812601*VXM+24.23729924*LAE08710
     *VXM**2.+67.95235861*VXM**3.-1.179384979*VXM**4.-55.05489748*VXM**5LAE08720
     *.+22.44144432*VXM**6.                                             LAE08730
               CDOB=CDOB+F                                              LAE08740
      CDALZ=CDOB                                                        LAE08750
      CDOT=1.1*(DCDOST*(STTOT/AREA)+CDOT)                               LAE08760
               IF (VXM.GT.1.1) CDOT =CDOT*2.*EXP(VXM-1.1)               LAE08770
      CDOW=1.1*(DCDOSW*(SWTOT/AREA)+CDOW)                               LAE08780
      CDOW2=1.1*(CDOW2+DCDOS2*(SWTOT/AREA))                             LAE08790
      CDOWBT=CDOB+CDOT+CDOW+CDOW2+CDMISC                                LAE08800
               IF (VXM.GT.1.1) CDOWBT=CDOWBT*1.1*EXP(1.1-VXM)           LAE08810
      TONST=CDOWBT                                                      LAE08820
      HONST=HONST+ZF*(TONST-HONST)                                      LAE08830
      IF (IZZY-4) 3010,3010,3030                                        LAE08840
 3010 VXM=VXMR1                                                         LAE08850
      IZZY = IZZY + 1                                                   LAE08860
      GO TO 1                                                           LAE08870
 3020 CDOWBT=((HONST-TONST)/(SQRT(3.)-SQRT(1.2)))*SQRT(VXM)+TONST       LAE08880
     *+(HONST-TONST)/(1.-SQRT(3.)/SQRT(1.2))                            LAE08890
               IF (VXM.GT.1.2) CDOWBT=CDOWBT*.5*EXP(.5*(1.2-VXM))+CDOWBTLAE08900
     */2.                                                               LAE08910
      CDOT=1.1*(DCDOT *(STTOT/AREA)+CDOT)                               LAE08920
               IF ((SQMITC.GT.1.3).OR.(VXM.GT.1.0)) CDOT=CDOT*.4*EXP(2.0LAE08930
     **(1.0-VXM))+CDOT*1.5                                              LAE08940
      CDOW=1.1*(DCDOW *(SWTOT/AREA)+CDOW)                               LAE08950
      CDOW2=1.1*(CDOW2+DCDOW2*(SWTOT/AREA))                             LAE08960
      CDOB=CDOWBT-CDOT-CDOW-CDOW2-CB                                    LAE08970
      CDALZ=CDOB                                                        LAE08980
 3030 CDB=XK2K1*SIN(2.*AL)*SIN(AL/2.)*3.14159*D*D/(4.*AREA)+ETA*        LAE08990
     *CDC*AP*((SIN(AL))**3)/AREA                                        LAE09000
      CLB=XK2K1*(SIN(2.*AL))*COS(AL/2.)*COS(AL)*3.14159*D*D/(4.*AREA)+ETLAE09010
     *A*CDC*AP*((SIN(AL))**2)*COS(AL)/AREA-CDALZ*COS(AL)*COS(AL)*SIN(A  LAE09020
     *L)                                                                LAE09030
      CA5=CDOWBT                                                        LAE09040
      IF(AL) 3050,3040,3050                                             LAE09050
 3040 XCPB=0.0                                                          LAE09060
      GO TO 3060                                                        LAE09070
 3050 XCPB=((XCG/XREF)-(CMB/CNB))*XREF                                  LAE09080
 3060 IF (SW) 3080,3080,3070                                            LAE09090
 3070 IF (ST) 3210,3210,3090                                            LAE09100
 3080 IF (ST) 3340,3340,3220                                            LAE09110
 3090 R=D/2.                                                            LAE09120
       IF (ICSC -1) 3110,3110,3100                                      LAE09130
 3100 XB1=BW/2.                                                         LAE09140
      XB2=BT/2.                                                         LAE09150
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      TT=D/BT                                                           LAE09160
      HW1=-0.5*CROOTT*ABS(SIN(DELTA))+(XCPWB-XTAIL-CROOTT)*ABS(SIN(AL)) LAE09170
      XLAM1=XLAMW                                                       LAE09180
      GO TO 3120                                                        LAE09190
 3110 XB1=BT/2.                                                         LAE09200
      XB2=BW/2.                                                         LAE09210
      TT=D/BW                                                           LAE09220
      HW1=-0.5*CROOTT*ABS(SIN(DELTA))+(XCPWB-XTAIL-CROOTT)*ABS(SIN(AL)) LAE09230
      XLAM1=XLAMT                                                       LAE09240
 3120 FTRT=((XB2-R)/(2.*(1.-TT)))*((3.14159/4.)-((3.14159*TT**2)/4.)-TT+LAE09250
     *(((1.+TT**2)**2)/(2.*(1.-TT**2)))*ARSIN((1.-TT**2)/(1.+TT**2)))   LAE09260
      FW=FTRT+R                                                         LAE09270
      FI2=(FW*R**2)/((FW**2)+(HW1**2))                                  LAE09280
      HI2=(HW1*R**2)/((FW**2)+(HW1**2))                                 LAE09290
      ZC=FW                                                             LAE09300
      ZD=HW1                                                            LAE09310
      ZLT=0.0                                                           LAE09320
      DO 3180 I=1,4                                                     LAE09330
      ZL1=((XB1-(XLAM1*R))-(ZC*(1.-XLAM1)))/(2.*(XB1-R))                LAE09340
      ZL2=ALOG(((ZD**2)+((ZC-XB1)**2))/((ZD**2)+((ZC-R)**2)))           LAE09350
      ZL3=((1.-XLAM1)/(XB1-R))*((XB1-R)+(ZD*(ATAN((ZC-XB1)/ZD)-ATAN((ZC-LAE09360
     *R)/ZD))))                                                         LAE09370
      ZL=(ZL1*ZL2)-ZL3                                                  LAE09380
      IF(I-2) 3130,3140,3140                                            LAE09390
 3130 ZC=-ZC                                                            LAE09400
      GO TO 3170                                                        LAE09410
 3140 IF(I-3) 3150,3160,3170                                            LAE09420
 3150 ZL=-ZL                                                            LAE09430
      ZC=FI2                                                            LAE09440
      ZD=HI2                                                            LAE09450
      GO TO 3170                                                        LAE09460
 3160 ZL=-ZL                                                            LAE09470
      ZC=-FI2                                                           LAE09480
 3170 ZLT=ZLT+ZL                                                        LAE09490
 3180 CONTINUE                                                          LAE09500
      IF(ICSC-1) 3190,3190,3200                                         LAE09510
 3190 ART=(BT-D)**2/ST                                                  LAE09520
      XBT=BT/2.                                                         LAE09530
      CLI=(CLALW*CLALT*XKWBI*SIN(AL)*SW*2.*ZLT*(XBT-R))/(2.*3.14159*ART*LAE09540
     *FTRT*AREA*(1.+XLAMT))                                             LAE09550
      CLI=CLI*COS(AL)                                                   LAE09560
      CLTP=CLTP+CLI                                                     LAE09570
      CLT=CLT+CLI                                                       LAE09580
      CLIT=CLI                                                          LAE09590
      CLIW=0.                                                           LAE09600
      XCPTV=XCPTB                                                       LAE09610
      GO TO 3230                                                        LAE09620
 3200 ARW=(BW-D)**2/SW                                                  LAE09630
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      XBW=BW/2.                                                         LAE09640
      CLI=(CLALW*CLALT*(XKWBI*SIN(AL)+XKTBI*SIN(DELTA))*ST*2.*ZLT*(XBW- LAE09650
     *R))/(2.*3.14159*ARW*FTRT*AREA*(1.+XLAMW))                         LAE09660
      CLI=CLI*COS(AL)                                                   LAE09670
      CLW=CLW+CLI                                                       LAE09680
      CLWP=CLWP+CLI                                                     LAE09690
      CLIW=CLI                                                          LAE09700
      CLIT=0.                                                           LAE09710
      XCPTV=XCPWB                                                       LAE09720
      GO TO 3230                                                        LAE09730
 3210 CLT=0.                                                            LAE09740
      CLALT=0.                                                          LAE09750
      CLTD=0.                                                           LAE09760
      CDTD=0.                                                           LAE09770
      CLBT=0.                                                           LAE09780
      CLBDT=0.                                                          LAE09790
      CLTB=0.                                                           LAE09800
      CLTDB=0.                                                          LAE09810
      CLVIST=0.                                                         LAE09820
      CLIT=0.                                                           LAE09830
      CLIW=0.                                                           LAE09840
      CLI=0.                                                            LAE09850
      CLTP=0.                                                           LAE09860
      GO TO 3230                                                        LAE09870
 3220 CLW=0.                                                            LAE09880
      CLALW=0.                                                          LAE09890
      CLBW=0.                                                           LAE09900
      CLWB=0.                                                           LAE09910
      CLVISW=0.                                                         LAE09920
      CLIW=0.                                                           LAE09930
      CLIT=0.                                                           LAE09940
      CLI=0.                                                            LAE09950
 3230 IF (SW2) 3240,3240,3250                                           LAE09960
 3240 CLW2=0.                                                           LAE09970
      CLALW2=0.                                                         LAE09980
      CLBW2=0.                                                          LAE09990
      CLWB2=0.                                                          LAE10000
C INDUCED DRAG                                                           LAE10010
 3250 ALPHA=AL                                                          LAE10020
      CLTOT=CLWP+CLTP+CLB+CLBW+CLBT                                     LAE10030
      IF(ARW.GT.3.0) GO TO 3260                                         LAE10040
      IF(VXM.GE..85) GO TO 3260                                         LAE10050
      CDI=ABS(CLTOT*TAN(ALPHA))                                         LAE10060
      GO TO 3270                                                        LAE10070
 3260 CDI=(CLTOT)**2/(PIE*BW**2*.7/AREA)                                LAE10080
 3270 IF(BT)3280,3290,3280                                              LAE10090
 3280 AR1=BT**2/AREA                                                    LAE10100
      CDTD=CLTD**2/(PIE*AR1*.7)                                         LAE10110
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      CDT=CDOT+(CLTP**2/(PIE*AR1*.7))                                    LAE10120
 3290 IF(BW2)3300,3310,3300                                              LAE10130
 3300 AR2=BW2**2/AREA                                                    LAE10140
      CDW2=CDOW2+(CLW2**2/(PIE*AR2*.7))                                  LAE10150
 3310 IF(BW)3320,3330,3320                                               LAE10160
 3320 AR3=BW**2/AREA                                                     LAE10170
      CDW=CDOW+(CLWP**2/(PIE*AR3*.7))                                    LAE10180
C   AXIAL AND NORMAL COMPONENTS                                          LAE10190
 3330 CATD=CDTD*COSAAL-CLTD*SINAAL                                       LAE10200
      CNTD=CLTD*COSAAL+CDTD*SINAAL                                       LAE10210
      CNT=CLT*COSAAL+CDT*SINAAL                                          LAE10220
      CNTP=(CLTP+CLTD)*COSAAL+(CDT+CDTD)*(SINAAL)                        LAE10230
      CNW=CLW*COSAAL+CDW*SINAAL                                          LAE10240
      CNWP=CLWP*COSAAL+CDW*SINAAL                                        LAE10250
      CNW2=CLW2*COSAAL+CDW2*SINAAL                                       LAE10260
      CAB=(CDOB+CDB)*COSAAL-CLB*SINAAL                                   LAE10270
      CAW=CDW*COSAAL-CLW*SINAAL                                          LAE10280
      CAW2=CDW2*COSAAL-CLW2*SINAAL                                       LAE10290
      CAT=CDT*COSAAL-CLT*SINAAL                                          LAE10300
      CA5=CAT+CAW+CAW2+CATD+CAB                                          LAE10310
      GO TO 3370                                                         LAE10320
 3340 CN=CNB                                                             LAE10330
      XCP2=XCPB                                                          LAE10340
      IF(XAL(J).GT.90.)GO TO 3350                                        LAE10350
      CA=CA5*COS(AL)*COS(AL)                                             LAE10360
      GO TO 3360                                                         LAE10370
 3350 CA51=-(.5667+.893*VXM-.1727*VXM*VXM)                               LAE10380
      CA=CA51*COS(AL)*COS(AL)                                            LAE10390
 3360 CONTINUE                                                           LAE10400
      CLTOT=CLB                                                          LAE10410
      CDTOT=CDB                                                          LAE10420
      CLALW=0.                                                           LAE10430
      CLALT=0.                                                           LAE10440
      CDT=0.                                                             LAE10450
      CDD=0.0                                                            LAE10460
      CDW=0.                                                             LAE10470
      CATD=0.                                                            LAE10480
      CNTD=0.                                                            LAE10490
      CNT=0.                                                             LAE10500
      CNTP=0.                                                            LAE10510
      CAT=0.                                                             LAE10520
      CAW=0.                                                             LAE10530
      CNW=0.                                                             LAE10540
      CNWP=0.                                                            LAE10550
      CLW=0.                                                             LAE10560
      CLWP=0.                                                            LAE10570
      CLT=0.                                                             LAE10580
      CLTP=0.                                                            LAE10590
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      CLTT=0.                                                           LAE10600
      CLI=0.                                                            LAE10610
      CLWT=0.                                                           LAE10620
      CLALW2=0.                                                         LAE10630
      CPW2=0.                                                           LAE10640
      CAW2=0.                                                           LAE10650
      CNTT=0.                                                           LAE10660
      CNWT=0.                                                           LAE10670
      CNWT2=0.                                                          LAE10680
      CNW2=0.                                                           LAE10690
      CLW2=0.                                                           LAE10700
      XCPW2=0.                                                          LAE10710
      XCPT=0.                                                           LAE10720
      XCPW=0.                                                           LAE10730
      GO TO 3490                                                        LAE10740
C TOTAL NORMAL,AXIAL, AND DRAG FORCE COEFFICIENTS                        LAE10750
 3370 CNBC=(CLBW+CLBT+CLBW2)*COSAAL                                     LAE10760
      CNTP=CLTP*COSAAL+CDT*SINAAL                                       LAE10770
      CNWP=CLWP*COSAAL+CDW*SINAAL                                       LAE10780
      CNW2=CLW2*COSAAL+CDW2*SINAAL                                      LAE10790
      CN=CNWP+CNTP+CNB+CNW2+CNBC                                        LAE10800
      CDI=CDI+CDB                                                       LAE10810
      CDTOT=CDOWBT+CDI+CDTD                                             LAE10820
      CA=CDTOT*COSAAL-CLTOT*SINAAL                                      LAE10830
C   TOTAL CENTER OF PRESSURE CALCULATIONS                               LAE10840
      XCPBC=(XCPBW*CLBW*COSAAL+XCPBT*CLBT*COSAAL+XCPBW2*CLBW2*COSAAL)   LAE10850
     */CNBC                                                             LAE10860
      IF (ST) 3390,3390,3380                                            LAE10870
 3380 XCPT=XCPTB                                                        LAE10880
 3390 IF (SW) 3420,3420,3400                                            LAE10890
 3400 XCPW=XCPWB                                                        LAE10900
      IF (SW2) 3420,3420,3410                                           LAE10910
 3410 XCPW2=XCPWB2                                                      LAE10920
 3420 IF (SW2) 3430,3430,3440                                           LAE10930
 3430 XCPW2=0.                                                          LAE10940
      CNW2=0.0                                                          LAE10950
      IF(SW) 3450,3450,3440                                             LAE10960
 3440 XCPW=((XCPW)*CNWP+(XCPW2)*CNW2)/(CNWP+CNW2)                       LAE10970
      CNWP=CNWP+CNW2                                                    LAE10980
      IF (SW) 3450,3450,3460                                            LAE10990
 3450 XCPW=0.                                                           LAE11000
 3460 IF (ST) 3470,3470,3480                                            LAE11010
 3470 XCPT=0.                                                           LAE11020
 3480 XCP2=(CNB*XCPB+XCPT*CNTP+XCPW*CNWP+XCPBC*CNBC)/(CNB+CNTP+CNWP+CNBCLAE11030
     *)                                                                 LAE11040
C   PITCHING MOMENT                                                     LAE11050
 3490 CM=CN*(XCG2-XCP2)/XREF                                            LAE11060
      AL1=AL*57.29578                                                   LAE11070
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C                                                                       LAE11080
C OUTPUT                                                                LAE11090
      WRITE(8,3500) AL1,CLTOT,CDTOT,CLWP,CLBW,CLTP,CLBT,CLB,CDI,CNWP,   LAE11100
     *CNTP,CLTD,CDTD,CN,CA,XCPW,XCPT,XCPB,XCP2,CM                       LAE11110
 3500 FORMAT(1X,F3.0,18(1X,F5.2),1X,F6.2)                               LAE11120
 3510 WRITE(6,3520)AL1,CLTOT,CDTOT,CLWP,CLBW,CLTP,CLBT,CLB,CDI,CNWP,CNTPLAE11130
 3520 FORMAT(1X,F3.0,10(1X,F6.2))                                       LAE11140
      WRITE (6,3530)CLTD,CDTD,CN,CA,XCPW,XCPT,XCPB,XCP2,CM              LAE11150
 3530 FORMAT(4X,9(1X,F6.2))                                             LAE11160
C++++++++++++++++++++++++++++++++++++++++                               LAE11170
C  THE FOLLOWING INSTRUCTIONS ARE FOR THE PLOT OUTPUT FACILITY          LAE11180
      IF (CLTOT.LT.CLMIN) CLMIN=CLTOT                                   LAE11190
      IF (CLTOT.GT.CLMAX) CLMAX=CLTOT                                   LAE11200
      CLM(IJ, II,J)=CLTOT                                               LAE11210
      CDM(IJ, II,J)=CDTOT                                               LAE11220
      CMM(IJ, II,J)=CM                                                  LAE11230
      CAM(IJ, II,J)=CA                                                  LAE11240
      CNM(IJ, II,J)=CN                                                  LAE11250
      CDIM(IJ,II,J)=CDI                                                 LAE11260
C++++++++++++++++++++++++++++++++++++++++                               LAE11270
      ALPHA = XAL(J+1)                                                  LAE11280
 3540 CONTINUE                                                          LAE11290
      WRITE(8,3560)CDINL,CDAFT,CDPROT,CDOB                              LAE11300
      WRITE(8,3570)CDOW,CDOT,CDMISC,CDOWBT                              LAE11310
 3550 WRITE (6,3560)CDINL,CDAFT,CDPROT,CDOB                             LAE11320
 3560 FORMAT(1X,'CDINL=',F6.4,' CDAFT=',F6.4,' CDPROT=',F6.4,' CDOB='   LAE11330
     *,F6.4)                                                            LAE11340
      WRITE (6,3570)CDOW,CDOT,CDMISC,CDOWBT                             LAE11350
 3570 FORMAT(1X,'CDOW=',F6.4,' CDOT=',F6.4,' CDMISC=',F6.4,' CDOWBT=',F6LAE11360
     *.4)                                                               LAE11370
C                                                                       LAE11380
      DELTA1=XDT(II+1)                                                  LAE11390
 3580 CONTINUE                                                          LAE11400
      VXM=XVXM(IJ+1)                                                    LAE11410
 3590 CONTINUE                                                          LAE11420
      IF (NBODY-IL) 3600,3600,1040                                      LAE11430
 3600 CONTINUE                                                          LAE11440
      CLAMW=CLAMW*57.29578                                              LAE11450
      CLAMT=CLAMT*57.29578                                              LAE11460
      WRITE (6,3610)                                                    LAE11470
 3610 FORMAT(/,1X,'DO YOU WANT ANOTHER RUN, 00=YES, 01=NO')             LAE11480
      READ(5,1060)IZXI                                                  LAE11490
      IF(IZXI.EQ.0)GO TO 1100                                           LAE11500
      CALL SCREEN                                                       LAE11510
C++++++++++++++++++++++++++++++++++++++++                               LAE11520
C  THE FOLLOWING INSTRUCTIONS ARE FOR THE PLOT OUTPUT FACILITY          LAE11530
      DC 4010 I=1,IM                                                    LAE11540
         DO 4010 J=1,IDT                                                LAE11550
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            DO 4010 K=1,IAL                                             LAE11560
               ALK=XAL(K)                                               LAE11570
               IF (ALK.LT.ALMIN)  ALMIN=ALK                             LAE11580
               IF (ALK.GT.ALMAX)  ALMAX=ALK                             LAE11590
               CDK=CDM(I,J,K)                                           LAE11600
               IF (CDK.LT.CDMIN)  CDMIN=CDK                             LAE11610
               IF (CDK.GT.CDMAX)  CDMAX=CDK                             LAE11620
               CMK=CMM(I,J,K)                                           LAE11630
               IF (CMK.LT.CMMIN)  CMMIN=CMK                             LAE11640
               IF (CMK.GT.CMMAX)  CMMAX=CMK                             LAE11650
               CAK=CAM(I,J,K)                                           LAE11660
               IF (CAK.LT.CAMIN)  CAMIN=CAK                             LAE11670
               IF (CAK.GT.CAMAX)  CAMAX=CAK                             LAE11680
               CNK=CNM(I,J,K)                                           LAE11690
               IF (CNK.LT.CNMIN)  CNMIN=CNK                             LAE11700
               IF (CNK.GT.CNMAX)  CNMAX=CNK                             LAE11710
               CDIK=CDIM(I,J,K)                                         LAE11720
               IF (CDIK.LT.CDIMIN) CDIMIN=CDIK                          LAE11730
               IF (CDIK.GT.CDIMAX) CDIMAX=CDIK                          LAE11740
4010           CONTINUE                                                 LAE11750
      WRITE(7,4020) IM,IDT,ICL,CLMAX,CLMIN                              LAE11760
4020  FORMAT(3I2,5X,2F6.2)                                              LAE11770
      DO 4060 I=1,IM                                                    LAE11780
         WRITE(7,4030) XVXM(I)                                          LAE11790
4030     FORMAT(F6.2)                                                   LAE11800
         DO 4070 J=1,IDT                                                LAE11810
            WRITE(7,4030) XDT(J)                                        LAE11820
            WRITE(7,4040)(CLM(I,J,K), K=1,24)                           LAE11830
4040        FORMAT(12F6.2/,12F6.2)                                      LAE11840
            WRITE(7,4050) ALMAX,ALMIN                                   LAE11850
4050        FORMAT(2F6.2)                                               LAE11860
            WRITE(7,4040) (XAL(K), K=1,24)                              LAE11870
            WRITE(7,4050) CDMAX,CDMIN                                   LAE11880
            WRITE(7,4040) (CDM(I,J,K), K=1,24)                          LAE11890
            WRITE(7,4050) CMMAX,CMMIN                                   LAE11900
            WRITE(7,4040) (CMM(I,J,K), K=1,24)                          LAE11910
            WRITE(7,4050) CAMAX,CAMIN                                   LAE11920
            WRITE(7,4040) (CAM(I,J,K), K=1,24)                          LAE11930
            WRITE(7,4050) CNMAX,CNMIN                                   LAE11940
            WRITE(7,4040) (CNM(I,J,K), K=1,24)                          LAE11950
            WRITE(7,4050) CDIMAX,CDIMIN                                 LAE11960
            WRITE(7,4040) (CDIM(I,J,K), K=1,24)                         LAE11970
4070        CONTINUE                                                    LAE11980
4060     CONTINUE                                                       LAE11990
      WRITE (7,4080)                                                    LAE12000
4080  FORMAT (1X,'/*')                                                  LAE12010
      STOP                                                              LAE12020
      END                                                               LAE12030
```

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C                                                                       LAE12040
C                                                                       LAE12050
C                                                                       LAE12060
      SUBROUTINE GEOSUB                                                 LAE12070
C   THIS SUBROUTINE CLACULATES THE MISSILE WETTED AREA AND THE          LAE12080
C   REYNOLDS NUMBER PER FOOT BASED ON THE FLIGHT ALTITUDE.              LAE12090
      DIMENSION XVXM(16),XDT(16),XAL(48)                                LAE12100
      COMMON  REFTI,REFT,SSUBS,XLOB,ZF,VXM,IZZY,LLKK,LLLL,NSURF         LAE12110
      COMMON  ICSC,INOSE,ISWPW,IAFBW,ISWPW2,IAFBW2,ISWPT,IAFBT,IDUM1,   LAE12120
     *CLAMT,CLAMW,CLAMW2,D,XLNOSE,BT,BW,BW2,CROOTW,CROOTT,CROOW2,       LAE12130
     *ST,SW,SW2,TOVCW,TOVCW2,TOVCT,XLAMT,XLAMW,XLAMW2,                  LAE12140
     *XMACW,XMACW2,XMACT,XWING,XWING2,XTAIL,HT,XL,AREA,XREF,            LAE12150
     *ISWEPW,ISWEPT,ISWEP2,NWING,NTAIL,NWING2,ENGINE,ENLET,BETA,DBASE,  LAE12160
     *DJET,XLABOD                                                       LAE12170
      COMMON  ART,ARW,ARW2,BAR,BCOLAM,BETA1,B1,CLALT,CLALW,CLALW2,CLAL1, LAE12180
     *COLAM,CROOT,IAFB,ISWP,TOVC,ODC,XBCRBW,XBCRWB,XKBT,XKBW,XKTB,XKTBT,LAE12190
     *XKWB,XKWBI,ISWP1,RATIO,XLAM1,XMAC,D1                              LAE12200
      DRAT=XLNOSE/D                                                     LAE12210
      DRAA=XLABOD/D                                                     LAE12220
      D1=D                                                              LAE12230
      XLOB=XL/D                                                         LAE12240
      IF(CLAMW-5.) 10,10,20                                             LAE12250
   10 CLAMW=5.                                                          LAE12260
   20 IF(CLAMW2-5.) 30,30,40                                            LAE12270
   30 CLAMW2=5.                                                         LAE12280
   40 IF(CLAMT-5.) 50,50,60                                             LAE12290
   50 CLAMT=5.                                                          LAE12300
   60 CONTINUE                                                          LAE12310
      CLAMW=CLAMW/57.29578                                              LAE12320
      CLAMT=CLAMT/57.29578                                              LAE12330
      CLAMW2=CLAMW2/57.29578                                            LAE12340
      IF (INOSE-1) 80,70,80                                             LAE12350
   70 SS1=(3.14*DRAT)+0.4                                               LAE12360
      GO TO 120                                                         LAE12370
   80 IF(INOSE-2) 100,90,100                                            LAE12380
   90 SS1=(2.68*DRAT)+0.1                                               LAE12390
      GO TO 120                                                         LAE12400
  100 IF(INOSE-3) 120,110,120                                           LAE12410
  110 SS1=(2.0*DRAT)+.2                                                 LAE12420
  120 SSUBS=3.14159*D*(XL-XLNOSE-XLABOD)+(SS1+2.68*DRAA*0.9)*(3.14159*D*LAE12430
     *D/4.0)                                                            LAE12440
      WRITE (6,130)SSUBS                                                LAE12450
  130 FCRMAT(1X,'NOSE WETTED AREA = ',F10.4,/)                          LAE12460
      IF(DRAT-.6) 140,140,150                                           LAE12470
  140 ZF=1.                                                             LAE12480
      GO TO 160                                                         LAE12490
  150 ZF=1.522*EXP(-.7*DRAT)                                            LAE12500
  160 Z=HT*0.001                                                        LAE12510
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```
      IF(HT-35332.0) 170,170,180                                        LAE12520
  170 T=519.-HT/1280.                                                   LAE12530
      PS=(1.91-0.01315*Z)**5.256                                        LAE12540
      GO TO 190                                                         LAE12550
  180 T=393.                                                            LAE12560
      B=1.69-0.0478*Z                                                   LAE12570
      PS=6.49*EXP(B)                                                    LAE12580
  190 C=49.1*SQRT(T)                                                    LAE12590
      PS=PS*70.9                                                        LAE12600
      RHO=PS/(1715.*T)                                                  LAE12610
      XMU=2.270*(T**1.5)/((T+198.6)*(10.**8))                           LAE12620
      REFT=(C*RHO)/XMU                                                  LAE12630
      WRITE (6,200)                                                     LAE12640
  200 FORMAT(1X,'IS THIS PROGRAM COMPARING EXPERIMENTAL DATA')          LAE12650
      WRITE (6,210)                                                     LAE12660
  210 FORMAT(1X,'ENTER 00=NO, 01=YES')                                  LAE12670
      READ 220,IEXP                                                     LAE12680
  220 FORMAT(I2)                                                        LAE12690
      REFTI=1000000.                                                    LAE12700
      IF(IEXP.EQ.0)GO TO 250                                            LAE12710
      WRITE (6,230)                                                     LAE12720
  230 FORMAT(1X,'ENTER REYNOLDS NUMBER/XREF OF EXPERIMENTAL DATA')      LAE12730
      READ 240, REFTI                                                   LAE12740
C     READ 240, REFT                                                    LAE12750
  240 FORMAT(F14.2)                                                     LAE12760
  250 CONTINUE                                                          LAE12770
      RETURN                                                            LAE12780
      END                                                               LAE12790
C                                                                       LAE12800
C                                                                       LAE12810
C                                                                       LAE12820
      SUBROUTINE CLASUB                                                 LAE12830
C   THIS SUBROUTINE CALCULATES THE AERODYNAMIC SURFACE LIFT-CURVE SLOPES.LAE12840
      DIMENSION XVXM(16),XDT(16),XAL(48)                                LAE12850
      COMMON REFTI,REFT,SSUBS,XLOB,ZF,VXM,IZZY,LLKK,LLLL,NSURF          LAE12860
      COMMON ICSC,INOSE,ISWPW,IAFBW,ISWPW2,IAFBW2,ISWPT,IAFBT,IDUM1,    LAE12870
     *CLAMT,CLAMW,CLAMW2,D,XLNOSE,BT,BW,BW2,CROOTW,CROOTT,CROOW2,       LAE12880
     *ST,SW,SW2,TOVCW,TOVCW2,TOVCT,XLAMT,XLAMW,XLAMW2,                  LAE12890
     *XMACW,XMACW2,XMACT,XWING,XWING2,XTAIL,HT,XL,AREA,XREF,            LAE12900
     *ISWEPW,ISWEPT,ISWEP2,NWING,NTAIL,NWING2,ENGINE,ENLET,BETA,DBASE,  LAE12910
     *DJET,XLABOD                                                       LAE12920
      COMMON ART,ARW,ARW2,BAR,BCOLAM,BETA1,B1,CLALT,CLALW,CLALW2,CLAL1, LAE12930
     *COLAM,CROOT,IAFB,ISWP,TOVC,ODC,XBCRBW,XBCRWB,XKBT,XKBW,XKTB,XKTBT,LAE12940
     *XKWB,XKWBI,ISWP1,RATIO,XLAM1,XMAC,D1                              LAE12950
      IF (VXM-1.)10,10,20                                               LAE12960
   10 BETA1=SQRT (1.-VXM**2)                                            LAE12970
      GO TO 30                                                          LAE12980
   20 BETA1=SQRT (VXM**2-1.)                                            LAE12990
```

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   30 IF(IZZY-4)510,510,40                                               LAE13000
   40 IF(VXM-1.)60,50,60                                                 LAE13010
   50 BETA1=0.0000001                                                    LAE13020
   60 KFIN=0                                                             LAE13030
      KFIN=KFIN+1                                                        LAE13040
      IF (SW) 420,420,70                                                 LAE13050
   70 ARW = (BW - D)**2/SW                                               LAE13060
      BAR=BETA1*ARW                                                      LAE13070
      ISWP=ISWPW                                                         LAE13080
      XLAM=XLAMW                                                         LAE13090
      AR=ARW                                                             LAE13100
   80 IF(BAR.GT.5.0.AND.VXM.GE.1.0)  BAR=5.0                             LAE13110
      IF(BAR.GT.5.0.AND.VXM.LT.1.0)  BAR=5.0                             LAE13120
      IF(ISWP-1) 90,90,200                                               LAE13130
   90 IF(XLAM-.25) 170,100,100                                           LAE13140
  100 IF(VXM-1.0) 110,110,120                                            LAE13150
  110 CLAR=-.1833*BAR+1.6                                                LAE13160
      GO TO 370                                                          LAE13170
  120 IF(XLAM-.50)130,140,150                                            LAE13180
  130 CLAR=-.001032518*BAR**8+.0200677*BAR**7-.1557225*BAR**6            LAE13190
     *+.607131*BAR**5-1.21537*BAR**4+1.13786*BAR**3-.5718*BAR**2         LAE13200
     *+.458487*BAR+1.57588                                               LAE13210
      GO TO 370                                                          LAE13220
  140 CLAR=.00121006*BAR**8-.0254597*BAR**7+.22119793*BAR**6             LAE13230
     *- 1.020448*BAR**5+2.651997*BAR**4-3.6809957*BAR**3                 LAE13240
     * +1.97903*BAR**2+.27640134*BAR+1.57129                             LAE13250
      GO TO 370                                                          LAE13260
  150 CLAR=-.00007776*BAR**8-.001814086*BAR**7+.051777483*BAR**6         LAE13270
     *-.43555555*BAR**5+1.7240831*BAR**4-3.3472653*BAR**3                LAE13280
     *+2.6137236*BAR**2-.23389542*BAR+1.57998                            LAE13290
      GO TO 370                                                          LAE13300
  170 IF(VXM-1.) 180,180,190                                             LAE13310
  180 CLAR=-.1667*BAR+1.575                                              LAE13320
      GO TO 370                                                          LAE13330
  190 IF(BAR-2.)200,200,210                                              LAE13340
  200 CLAR=.00133364*BAR**5-.0318237*BAR**4+.26049*BAR**3-.8643*BAR**2   LAE13350
     *+.669396*BAR+2.2008                                                LAE13360
      GO TO 370                                                          LAE13370
  210 CLAR=-.040277*BAR**4+.222522*BAR**3-.48931*BAR**2+.47287*BAR+1.57  LAE13380
      GO TO 370                                                          LAE13390
  220 IF (XLAM-.1) 230,300,300                                           LAE13400
  230 IF(VXM-1.) 240,240,250                                             LAE13410
  240 CLAR=-.2077*BAR+1.575                                              LAE13420
      GO TO 370                                                          LAE13430
  250 IF(BAR-.25) 260,260,270                                            LAE13440
  260 CLAR=.2077*BAR+1.575                                               LAE13450
      GO TO 370                                                          LAE13460
  270 IF(BAR-4.) 280,280,290                                             LAE13470
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280 CLAR=-.1668*BAR+1.667                                              LAE13480
    GO TO 370                                                          LAE13490
290 CLAR=1.587*(1.26)**(2.-BAR)                                        LAE13500
    GO TO 370                                                          LAE13510
300 IF (XLAM-.3) 310,340,340                                           LAE13520
310 IF(VXM-1.) 320,320,330                                             LAE13530
320 CLAR=-.2065*BAR+1.6                                                LAE13540
    GO TO 370                                                          LAE13550
330 CLAR=.002119027*BAR**5-.03283282*BAR**4+.20366375*BAR**3           LAE13560
   *-.61820362*BAR**2+.62703849*BAR+1.550048                           LAE13570
    GO TO 370                                                          LAE13580
340 IF(VXM-1.) 350,350,360                                             LAE13590
350 CLAR=-.225*BAR+1.675                                               LAE13600
    GO TO 370                                                          LAE13610
360 IF(XLAM.LE..40)CLAR=.00070428*BAR**8-.0158837*BAR**7               LAE13620
   *+.1489347*BAR**6-.74733673*BAR**5+2.1861823*BAR**4                 LAE13630
   *-3.3445976*BAR**3+2.2919403*BAR**2-.21045286*BAR+1.6203524         LAE13640
    IF(XLAM.GT..40)CLAR=-.00012278513*BAR**8+.0000879756*BAR**7        LAE13650
   *+.025071933*BAR**6-.25587433*BAR**5+1.0834904*BAR**4               LAE13660
   *-2.1562044*BAR**3+1.6307710*BAR**2-.084287165*BAR+1.7039           LAE13670
370 CLAL=CLAR*AR                                                       LAE13680
    IF (KFIN-2) 380,390,400                                            LAE13690
380 CLALW=CLAL                                                         LAE13700
    GO TO 410                                                          LAE13710
390 CLALW2=CLAL                                                        LAE13720
    GO TO 410                                                          LAE13730
400 CLALT=CLAL                                                         LAE13740
410 IF (KFIN-2) 420,440,500                                            LAE13750
420 KFIN=KFIN+1                                                        LAE13760
    IF (SW2) 440,440,430                                               LAE13770
430 AR=(BW2-D)**2/SW2                                                  LAE13780
    BAR=BETA1*AR                                                       LAE13790
    ISWP=ISWPW2                                                        LAE13800
    ARW2=AR                                                            LAE13810
    XLAM=XLAMW2                                                        LAE13820
    GO TO 80                                                           LAE13830
440 KFIN=KFIN+1                                                        LAE13840
    IF (ST) 460,460,450                                                LAE13850
450 AR=(BT-D)**2/ST                                                    LAE13860
    BAR=BETA1*AR                                                       LAE13870
    ART=AR                                                             LAE13880
    ISWP=ISWPT                                                         LAE13890
    NSURF=NTAIL                                                        LAE13900
    XLAM=XLAMT                                                         LAE13910
    GO TO 80                                                           LAE13920
460 IF (SW) 470,470,500                                                LAE13930
470 IF (SW2) 480,480,500                                               LAE13940
480 IF (ST) 490,490,500                                                LAE13950
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```
  490 LLLL=2
      RETURN
  500 LLKK=0
  510 IZZY =  IZZY + 1
      IF (SW) 530,530,520
  520 COLAM= COS(CLAMW)/(SIN(CLAMW+.1))
      ARW=(BW-D)**2/SW
      BCOLAM=BETA1*COLAM
      CROOT=CROOTW
      B1=BW
      IAFB=IAFBW
      XMAC=XMACW
      TOVC=TOVCW
      CLAL1=CLALW
      XLAM1=XLAMW
      ISWP1=ISWPW
      NSURF=NWING
      BAR=BETA1*ARW
      RATIO=CROOT/(BETA1*D)
      LLLL=0
      RETURN
  530 IZZY =  IZZY + 1
      IF (SW2) 540,540,550
  540 LLLL=1
      RETURN
  550 COLAM=COS(CLAMW2)/(SIN(CLAMW2+.1))
      BCOLAM=BETA1*COLAM
      CROOT=CROOW2
      B1=BW2
      IAFB=IAFBW2
      CLAL1=CLALW2
      XLAM1=XLAMW2
      NSURF=NWING2
      XMAC=XMACW2
      TOVC=TOVCW2
      ISWP1=ISWPW2
      ARW2=(BW2-D)**2/SW2
      BAR=BETA1*ARW2
      RATIO=CROOT/(BETA1*D)
      LLLL=0
      RETURN
      END
C
C
C
      SUBROUTINE CATSUB
C   THIS SUBROUTINE CALCULATES CENTER OF PRESSURE LOCATIONS, CROSS-FLOW
C   DRAG COEFFICIENTS, AND INTERFERENCE FACTORS.
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      DIMENSION XVXM(16),XDT(16),XAL(48)                                LAE14440
      COMMON REFTI,REFT,SSUBS,XLOB,ZF,VXM,IZZY,LLKK,LLLL,NSURF          LAE14450
      COMMON ICSC,INOSE,ISWPW,IAFBW,ISWPW2,IAFBW2,ISWPT,IAFBT,IDUM1,    LAE14460
     1CLAMT,CLAMW,CLAMW2,D,XLNOSE,BT,BW,BW2,CROOTW,CROOTT,CROOW2,       LAE14470
     2ST,SW,SW2,TOVCW,TOVCW2,TOVCT,XLAMT,XLAMW,XLAMW2,                  LAE14480
     3XMACW,XMACW2,XMACT,XWING,XWING2,XTAIL,HT,XL,AREA,XREF,            LAE14490
     4ISWEPW,ISWEPT,ISWEP2,NWING,NTAIL,NWING2,ENGINE,ENLET,BETA,DBASE,  LAE14500
     5DJET,XLABOD                                                       LAE14510
      COMMON ART,ARW,ARW2,BAR,BCOLAM,BETA1,B1,CLALT,CLALW,CLALW2,CLAL1, LAE14520
     1COLAM,CROOT,IAFB,ISWP,TOVC,ODC,XBCRBW,XBCRWB,XKBT,XKBW,XKTB,XKTBT,LAE14530
     2XKWB,XKWBI,ISWP1,RATIO,XLAM1,XMAC,D1                              LAE14540
      XKWB=(2./3.14159)*((1.+D**4/B1**4)*(.5*ATAN(.5*(B1/D-D/B1))+3.1415LAE14550
     19/4.)-(D**2/B1**2)*((B1/D-D/B1)+2.*ATAN(D/B1)))/(1.-D/B1)**2      LAE14560
   10 XKTB1=((3.14159)**2*D**2*(B1/D+1.)**2)/(4.*B1**2)+(3.14159*D**2*(BLAE14570
     11**2/D**2+1.)**2/(B1**2*(B1/D-1.)**2))*ARSIN((B1**2/D**2-1.)/(B1**LAE14580
     22/D**2+1.))                                                       LAE14590
      XKTB2=2.*3.14159*D*(B1/D+1.)/(B1*(B1/D-1.))-((B1**2/D**2+1.)**2/((LAE14600
     1B1**2/D**2)*(B1/D-1.)**2))*(ARSIN((B1**2/D**2-1.)/(B1**2/D**2+1.))LAE14610
     2)**2                                                              LAE14620
      XKTB3=(4.*D*(B1/D+1.)/(B1*(B1/D-1.)))*ARSIN((B1**2/D**2-1.)/(B1**2LAE14630
     1/D**2+1.))-(8./(B1/D-1.)**2)*ALOG10((B1**2/D**2+1.)/(2.*B1/D))    LAE14640
      XKTB=(1./(3.14159)**2)*(XKTB1-XKTB2-XKTB3)                        LAE14650
      IF (ICSC-1) 20,20,40                                              LAE14660
   20 IF (LLKK) 30,30,50                                                LAE14670
   30 XKWBI=D/B1+1.                                                     LAE14680
       XKTBI=XKTB                                                       LAE14690
      GO TO 50                                                          LAE14700
   40 IF (LLKK-1) 50,50,30                                              LAE14710
   50 BAREF=BAR*(1.+XLAM1)*((1./(BETA1*COLAM))+1.)                      LAE14720
      IF (BAREF-4.) 60,60,70                                            LAE14730
   60 XKBW=(1.+D/B1)**2-XKWB                                            LAE14740
      GC TO 180                                                         LAE14750
   70 IF (IAFB) 80,110,80                                               LAE14760
   80 IF (BCOLAM-1.) 100,90,90                                          LAE14770
   90 XKBW1=(BCOLAM/(1.+BCOLAM))*((((BCOLAM+1.)*(1./RATIO)+BCOLAM)/BCOLALAE14780
     1M)**2)*ARCOS((1.+(1.+BCOLAM)*(1./RATIO))/(BCOLAM+(BCOLAM+1.)*(1./ LAE14790
     2RATIO)))                                                          LAE14800
      XKBW2=(SQRT(BCOLAM**2-1.)/(BCOLAM+1.))*(SQRT(1.+2.*BETA1*D/CROOT)-LAE14810
     11.)-(SQRT(BCOLAM**2-1.)/BCOLAM)*(BETA1*D/CROOT)**2*ALOG((1.+CROOT/LAE14820
     2(BETA1*D))+SQRT((1.+CROOT/(BETA1*D))**2-1.))-(BCOLAM/(1.+BCOLAM))*LAE14830
     3ARCOS(1./BCOLAM)                                                  LAE14840
      XKBW=(8.*BCOLAM/(3.14159*SQRT(BCOLAM**2-1.)*(1.+XLAM1)*(BETA1*D/  LAE14850
     1CROOT)*(B1/D-1.)*(BETA1*CLAL1)))*(XKBW1+XKBW2)                    LAE14860
      GO TO 180                                                         LAE14870
  100 XKBW1=((BCOLAM+(1.+BCOLAM)*BETA1*D/CROOT)/BCOLAM)**1.5+((BCOLAM+(1LAE14880
     1.+BCOLAM)*BETA1*D/CROOT)/BCOLAM)**.5-2.                           LAE14890
      XKBW2=(((1.+BCOLAM)*BETA1*D/CROOT)/BCOLAM)**2*0.5*(ALOG(1.+SQRT(BCLAE14900
     1OLAM/(BCOLAM+(1.+BCOLAM)*BETA1*D/CROOT)))-ALOG(1.-SQRT(BCOLAM/(BCOLAE14910
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     2LAM+(1.+BCOLAM)*BETA1*D/CROOT))))                                 LAE14920
      XKBW=(16.*(BCOLAM/(1.+BCOLAM))**2/(3.14159*(1.+XLAM1)*(BETA1*D/   LAE14930
     1CROOT)*(B1/D-1.)*(BETA1*CLAL1)))*(XKBW1-XKBW2)                    LAE14940
      GO TO 180                                                         LAE14950
  110 IF(BCOLAM-1.) 150,120,120                                         LAE14960
  120 IF(RATIO-1.) 130,140,140                                          LAE14970
  130 RATIO=1.                                                          LAE14980
      D=CROOT/BETA1                                                     LAE14990
  140 XKB1=(1.+COLAM*BETA1*RATIO)**2*ARCOS((BCOLAM+RATIO)/(1.+COLAM*BETALAE15000
     11*RATIO))                                                         LAE15010
      XKB2=BCOLAM**2*RATIO**2*ARCOS(1./BCOLAM)-BCOLAM*RATIO**2*SQRT(BCOLLAE15020
     1AM**2-1.)*ARSIN(1./RATIO)                                         LAE15030
      XKB3=SQRT(BCOLAM**2-1.)*ALOG(RATIO+SQRT(RATIO**2-1.))             LAE15040
      XKBW=((8./(3.14159*SQRT(BCOLAM**2-1.)*BETA1*CLAL1*(XLAM1+1.)*(B1/DLAE15050
     11-1.)))*(1./RATIO))*(XKB1-XKB2-XKB3)                              LAE15060
      GO TO 180                                                         LAE15070
  150 IF(RATIO-1.) 160,170,170                                          LAE15080
  160 RATIO=1.                                                          LAE15090
      D=CROOT/BETA1                                                     LAE15100
  170 XKB1=(1.+COLAM*BETA1*RATIO)*SQRT((RATIO-1.)*(COLAM*BETA1*RATIO+1.)LAE15110
     1)                                                                 LAE15120
      XKB2=RATIO**2*(BCOLAM)**1.5-BCOLAM*RATIO**2*(BCOLAM+1.)*(ATAN(SQRTLAE15130
     1(1./BCOLAM))-ATAN(SQRT((RATIO-1.)/(COLAM*BETA1*RATIO+1.))))       LAE15140
      XKB3=((BCOLAM+1.)/SQRT(BCOLAM))*0.5*(ALOG(1.+SQRT(BCOLAM*(RATIO-1.LAE15150
     1)/(COLAM*BETA1*RATIO+1.)))-ALOG(1.-SQRT(BCOLAM*(RATIO-1.)/(COLAM* LAE15160
     2BETA1*RATIO+1.))))                                                LAE15170
      XKBW=((16.*SQRT(BCOLAM)*(1./RATIO)/(BETA1*CLAL1*(XLAM1+1.)*(B1/D1 LAE15180
     1-1.)*3.14159*(BCOLAM+1.))))*(XKB1-XKB2-XKB3)                      LAE15190
  180 XKBT=XKWB-XKTB                                                    LAE15200
      D=D1                                                              LAE15210
      IF(VXM-1.0) 190,190,320                                           LAE15220
  190 IF(ISWP1-1  ) 200,200,230                                         LAE15230
  200 IF(BAR-2.0) 210,220,220                                           LAE15240
  210 XBCRWB=0.35-XLAM1*(0.35+17.885-SQRT(328.8782-(BAR-3.)**2))        LAE15250
      GO TO 260                                                         LAE15260
  220 XBCRWB=0.35-0.1*XLAM1                                             LAE15270
      GO TO 260                                                         LAE15280
  230 IF(BAR-2.0) 240,250,250                                           LAE15290
  240 XCR1=SQRT(2029.5+(BAR-3.)**2)                                     LAE15300
      XBCRWB=((-44.5+XCR1)-XLAM1*(-44.5+XCR1+17.885-SQRT(328.8782-(BAR  LAE15310
     1-3.)**2)))                                                        LAE15320
      GO TO 290                                                         LAE15330
  250 XBCRWB=0.55-0.3*XLAM1                                             LAE15340
      GO TO 290                                                         LAE15350
  260 IF(BAR-4.0) 270,280,280                                           LAE15360
  270 XBCRBW=0.25-XLAM1*(32.125-SQRT(1032.02-(BAR-4.)**2))+(1.-XLAM1)*  LAE15370
     1ALOG(1.04+0.1*D/B1)*(-7.5+SQRT(72.25-(BAR-4.0)**2))               LAE15380
      GO TO 520                                                         LAE15390
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280 XBCRBW=0.25+((1.-XLAM1)*ALOG(1.04+0.1*D/B1))                      LAE15400
    GO TO 520                                                         LAE15410
290 IF(BAR-4.0) 300,310,310                                           LAE15420
300 XBCRBW=0.25+(1.-2.*XLAM1)*(32.125-SQRT(1032.02-(BAR-4.)**2))+     LAE15430
   1(1.-XLAM1)*ALOG(1.12+0.3*D/B1)*(-7.5+SQRT(72.25-(BAR-4.)**2))     LAE15440
    GO TO 520                                                         LAE15450
310 XBCRBW=0.25+(1.-XLAM1)*ALOG(1.12+0.3*D/B1)                        LAE15460
    GO TO 520                                                         LAE15470
320 IF(ISWP1-1  ) 330,330,360                                         LAE15480
330 IF(BAR-3.0) 340,350,350                                           LAE15490
340 XBCRWB=-(9.235+25.*(1.-XLAM1))+SQRT((9.71+25.*(1.-XLAM1))**2-     LAE15500
   1(BAR-3.)**2)                                                      LAE15510
    GO TO 390                                                         LAE15520
350 XBCRWB=0.005*BAR+0.46                                             LAE15530
    GO TO 390                                                         LAE15540
360 IF(BAR-3.) 370,380,380                                            LAE15550
370 XBCRWB=0.675-XLAM1*(0.675+9.235-SQRT(94.1-(BAR-3.)**2))           LAE15560
    GO TO 490                                                         LAE15570
380 XBCRWB=0.005*BAR+0.46+0.2*(1.-XLAM1)                              LAE15580
    GO TO 490                                                         LAE15590
390 BARLAM=BAR*(1.-XLAM1)*(1.+(1./BCOLAM))                            LAE15600
    IF(BARLAM-4.0) 400,400,440                                        LAE15610
400 IF(BAR-2.0) 410,430,430                                           LAE15620
410 XBMID1 = ALOG(1.32 - 0.32*XLAM1)                                  LAE15630
420 XBMID2=4.+(XBMID1**2)-((0.5+0.5139*(D/B1)*(1.17+XLAM1)*(1./(0.331 LAE15640
   1**(D/B1)))))**2)                                                  LAE15650
    XBMID3=2.*((XBMID1)-(0.5+0.5139*(D/B1)*(1.17+XLAM1)*(1./(0.331    LAE15660
   1**(D/B1))))))                                                     LAE15670
    XBMID=XBMID2/XBMID3                                               LAE15680
    XCMID=4.+(XBMID1-XBMID)**2                                        LAE15690
    XBCRBW=SQRT(XCMID-((BAR-2.)**2))+XBMID                            LAE15700
    GO TO 520                                                         LAE15710
430 XBCRBW=0.5+0.25695*(D/B1)*(1./(0.331**(D/B1)))*BAR*(1.17+XLAM1)   LAE15720
    GO TO 520                                                         LAE15730
440 IF(IAFB) 450,450,480                                              LAE15740
450 IF(RATIO-1.0) 460,460,470                                         LAE15750
460 XBCRBW=0.67                                                       LAE15760
    GO TO 520                                                         LAE15770
470 XBCRBW=-2.32+SQRT(8.9401-((1./RATIO)-1.)**2)                      LAE15780
    GO TO 520                                                         LAE15790
480 XBCRBW=(0.429/RATIO)+0.5                                          LAE15800
    GO TO 520                                                         LAE15810
490 BARLAM=BAR*(1.-XLAM1)*(1.+(1./BCOLAM))                            LAE15820
    IF(BARLAM-4.0) 500,500,440                                        LAE15830
500 IF(BAR-2.0) 510,430,430                                           LAE15840
510 XBMID1=ALOG(1.65-0.65*XLAM1)                                      LAE15850
    GO TO 420                                                         LAE15860
520 D=D1                                                              LAE15870
```

```
      ARAT=BAR/BETA1                                                    LAE15880
      IF(ARAT-4.0) 540,540,530                                          LAE15890
  530 ARAT=4.0                                                          LAE15900
  540 ODC=2.*(1.+XLAM1)**1.6*EXP(-.4*ARAT)                              LAE15910
      IF(ARAT-1.0) 580,550,550                                          LAE15920
  550 IF(XLAM1.LE.0.25) GO TO 560                                       LAE15930
      IF(XLAM1.LE.0.75) GO TO 570                                       LAE15940
      ODC=ODC-.25*(ARAT-1.)                                             LAE15950
      IF(ARAT.LT.2.0) GO TO 580                                         LAE15960
      ODC=(2.*(1.+XLAM1)**1.6)*.45-(.85*(ARAT-2.))                      LAE15970
      GO TO 580                                                         LAE15980
  560 ODC=(2.*(1.+XLAM1)**1.6)*.67-(.3*(ARAT-1.0))                      LAE15990
      GO TO 580                                                         LAE16000
  570 ODC=(2.*(1.+XLAM1)**1.6)*.67-(.725*(ARAT-1.))                     LAE16010
  580 CONTINUE                                                          LAE16020
      RETURN                                                            LAE16030
      END                                                               LAE16040
C                                                                       LAE16050
C                                                                       LAE16060
      SUBROUTINE SCREEN                                                 LAE16070
      WRITE (6,500)                                                     LAE16080
  500 FORMAT (/1X,'CLEAR SCREEN AND ENTER "0"')                         LAE16090
      READ (6,16) ISCR                                                  LAE16100
   16 FORMAT (1I1)                                                      LAE16110
      RETURN                                                            LAE16120
      END                                                               LAE16130
```

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//AEROPLOT JOB (1414,0483,,24),'LINDSEY',CLASS=A                    LAE00040
// EXEC FRTXCLGP                                                     LAE00050
//FORT.SYSIN DD *                                                    LAE00060
C.***********PROGRAM AEROPLOT****************                        LAE00070
C                                                                    LAE00080
C  PROGRAM AEROPLOT PLOTS DIMENSIONLESS AERODYNAMIC COEFFIEIENTS     LAE00090
C  CD TOTAL, CM,CA,DN,CD INDUCED AND ANGLE OF ATTACK AS A            LAE00100
C. FUNCTION OF LIFT COEFFICIENT.  A SEPERATE PLOT IS GENERATED       LAE00110
C  FOR EACH MACH NUMBER (MAX OF 30 MACH NUMBERS) ALLOWING FOR UP     LAE00120
C. TO 10 DIFFERENT CONTROL SURFACE DEFLECTIONS FOR EACH PLOT.        LAE00130
C. THE PROGRAM USES VERSAPLOT SOFTWARE FOR USE ON THE IBM 3033       LAE00140
C. COMPUTER.  ACTUAL PLOTTING IS ACCOMPLISHED VIA SUBROUTINE         LAE00150
C. "GRAPH" TO PERMIT RELATIVELY PAINLESS TRANSITION TO OTHER         LAE00160
C. SOFTWARE, THOUGH LOCATION OF ORIGIN FOR THE VARIOUS PLOTS ARE     LAE00170
C. DETERMINED IN MAIN PROGRAM.                                       LAE00180
C                                                                    LAE00190
C.VARIABLES USED IN COMMON BLOCKS ARE AS FOLLOWS.                    LAE00200
C.      1. ASCALE - CONTAINS THE INITIAL PLOTTING VALUE AND PLOT     LAE00210
C.           INCREMENT FOR ALL 6 PLOT PARAMETERS.  PLOT INCREMENTS   LAE00220
C.           ARE DETERMINED SUCH THAT EACH PLOT IS ON A 5" X 5"      LAE00230
C.           AXIS                                                    LAE00240
C                                                                    LAE00250
C.      2. ISYMBL - CONTAINS THE INTEGER DESIGNATION OF THE PLOTTING LAE00260
C.           SYMBOL USED IN GRAPHING                                 LAE00270
C                                                                    LAE00280
C. OTHER VARIABLES:                                                  LAE00290
C       1. LEGEND - ARRAY OF 10 PLOTTING SYMBOL INTEGERS USED TO     LAE00300
C.           PRODUCE A LEGEND OF SYMBOLS CORRESPONDING TO THE VARIOUS LAE00310
C.           CONTROL SURFACE DEFLECTIONS USED.                       LAE00320
C                                                                    LAE00330
C.      2. DELTA - ARRAY OF CONTROL SURFACE DEFLECTION ANGLES        LAE00340
C                                                                    LAE00350
C.      3. IFLAG - FLAG WHICH DETERMINES IF COORDINATE AXES ARE      LAE00360
C.           TO BE PLOTTED (1), OR IF ANOTHER DELTA VALUE IS TO      LAE00370
C.           BE PLOTTED ON AN ALREADY EXISTING GRAPH (0).            LAE00380
C                                                                    LAE00390
C. ALL DATA TO BE PLOTTED IS GENERATED FROM AN EXTERNAL SOURCE.      LAE00400
C. NO COEFFICIENT CALCULATIONS ARE MADE IN THIS PROGRAM.             LAE00410
C.                                                                   LAE00420
C. LT. GREY HOBBY USN                  MARCH 1981                    LAE00430
C*****************************************************               LAE00440
C.                                                                   LAE00450
      DIMENSION CL(24),DELTA(14),LEGEND(10)                          LAE00460
      REAL MACH                                                      LAE00470
      COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,             LAE00480
     +FCDT,DCDT,FCA,DCA,FCN,DCN                                      LAE00490
      COMMON/ISYMBL/NSYMB                                            LAE00500
      DATA LEGEND /1,2,3,4,5,6,7,8,9,10/                             LAE00510
```

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C                                                                       LAE00520
C                                                                       LAE00530
C                                                                       LAE00540
C.   ENTER NUMBER OF MACH,NUMBER OF DELTA/MACH,NUMBER OF CL AND         LAE00550
C.   MAX,MIN CL                                                         LAE00560
      READ(5,900)NMACH,NDEL ,NCL,CLMAX,CLMIN                            LAE00570
C                                                                       LAE00580
C.   SET UP PLOTTING WINDOW TO ALLOW PLOTTING SPACE FOR UP              LAE00590
C.   TO 30 MACH NUMBERS                                                 LAE00600
      XMACH=FLOAT(NMACH)                                                LAE00610
      XPLOT=21.1 *XMACH                                                 LAE00620
      CALL WINDOW(0.,XPLOT,0.,XPLOT)                                    LAE00630
C                                                                       LAE00640
C===============PLOTTING STARTS HERE===============                     LAE00650
C   INITIALIZE PLOT                                                     LAE00660
      CALL PLOTS(0,0,0)                                                 LAE00670
C.   MOVE ORIGIN TO ALLOW SPACE FOR AXIS LABELS AND TITLES              LAE00680
      CALL PLOT(1.,1.,-3)                                               LAE00690
C                                                                       LAE00700
C.   READ MACH AND PLOT ALPHA, CM,CDTOT,CA,CLTOT,CN                     LAE00710
      DO 100 I=1,NMACH                                                  LAE00720
C.   SET UP FLAG FOR AXIS PLOT AND PLOT SYMBOL DESIGNATION              LAE00730
      NSYMB=1                                                           LAE00740
      IFLAG=1                                                           LAE00750
      READ(5,902) MACH                                                  LAE00760
C                                                                       LAE00770
C.   PLOT DATA FOR EACH MACH NUMBER                                     LAE00780
      DO 90 J=1,NDEL                                                    LAE00790
C.   READ DELTA                                                         LAE00800
      READ(5,902) DELTA(J)                                              LAE00810
C.   READ CL DATA                                                       LAE00820
      READ(5,901)CL                                                     LAE00830
C.                                                                      LAE00840
C.   PLOT ANGLE OF ATTACK                                               LAE00850
      CALL ALPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                             LAE00860
C.   REORIGIN AND PLOT TOTAL DRAG COEFFICIENT                           LAE00870
      CALL PLOT(5.75,0.0,-3)                                            LAE00880
      CALL CDTPLT(NCL,CL,CLMIN,CLMAX,IFLAG)                             LAE00890
      CALL PLOT(-5.75,0.,-3)                                            LAE00900
C.   REORIGIN AND PLOT PITCHING MOMENT                                  LAE00910
      CALL PLOT(0.,5.75,-3)                                             LAE00920
      CALL CMPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                             LAE00930
      CALL PLOT(0.,-5.75,-3)                                            LAE00940
C.   REORIGIN AND PLOT CA                                               LAE00950
      CALL PLOT(5.75,5.75,-3)                                           LAE00960
      CALL CAPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                             LAE00970
      CALL PLOT(-5.75,-5.75,-3)                                         LAE00980
C.   REORIGIN AND PLOT NORMAL FORCE                                     LAE00990
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      CALL PLOT(0.,11.5,-3)                                             LAE01000
      CALL CNPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                             LAE01010
      CALL PLOT(0.,-11.5,-3)                                            LAE01020
C.   REORIGIN AND PLOT INDUCED DRAG                                     LAE01030
      CALL PLOT(5.75,11.5,-3)                                           LAE01040
      CALL CDPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                             LAE01050
      CALL PLOT(-5.75,-11.5,-3)                                         LAE01060
C                                                                       LAE01070
C.   INCREMENT SYMBOL NUMBER AND ZERO AXIS FLAG                         LAE01080
      NSYMB=NSYMB+1                                                     LAE01090
      IFLAG=0                                                           LAE01100
90    CONTINUE                                                          LAE01110
C.                                                                      LAE01120
C.   LABEL PLOT WITH MACH NUMBER                                        LAE01130
      CALL NEWPEN(3)                                                    LAE01140
      CALL SYMBOL(4.5,-1.0,.25,'MACH = ',0.0,7)                         LAE01150
      CALL NUMBER(6.25,-1.0,.25,MACH,0.0,2)                             LAE01160
C.   PRINT LEGEND FOR DELTA PLOTTING SYMBOLS                            LAE01170
      XSYMB=9.75                                                        LAE01180
      YSYMB=17.0                                                        LAE01190
      XDEL=10.0                                                         LAE01200
      DO 95 J=1,NDEL                                                    LAE01210
C.   PRINT PLOTTING SYMBOL                                              LAE01220
      CALL SYMBOL(XSYMB,YSYMB,0.1,LEGEND(J),0.,-1)                      LAE01230
C.   PRINT DELTA VALUE                                                  LAE01240
      CALL NUMBER(XDEL,YSYMB,0.1,DELTA(J),0.,-1)                        LAE01250
C.   INCREMENT PLOTTING SYMBOL AND PRINT COORDINATES                    LAE01260
      YSYMB=YSYMB+0.15                                                  LAE01270
   95 CONTINUE                                                          LAE01280
C.   LABEL THE LEGEND                                                   LAE01290
      YSYMB=YSYMB+0.15                                                  LAE01300
      CALL SYMBOL(9.5,YSYMB,0.1,'DELTA LEGEND:',0.,13)                  LAE01310
C.   LABEL PLOTTING GRAPH                                               LAE01320
      CALL SYMBOL(3.,19.5,.25,'AERODYNAMIC COEFFICIENTS',0.,24)         LAE01330
C                                                                       LAE01340
C.   MOVE TO NEXT MACH PLOTTING POSITION                                LAE01350
      CALL PLOT(12.5,0.,-3)                                             LAE01360
C                                                                       LAE01370
100   CONTINUE                                                          LAE01380
C                                                                       LAE01390
C.   TERMINATE PLOT                                                     LAE01400
      CALL PLOT(0.,0.,+999)                                             LAE01410
C                                                                       LAE01420
C.***********FORMATS***********                                         LAE01430
900   FORMAT(3I2,5X,2F6.2)                                              LAE01440
901   FORMAT(12F6.2,/,12F6.2)                                           LAE01450
902   FORMAT(F6.2)                                                      LAE01460
C*****************************                                          LAE01470
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C                                                                       LAE01480
      STOP                                                              LAE01490
      END                                                               LAE01500
C.                                                                      LAE01510
C.                                                                      LAE01520
      SUBROUTINE GETDAT(YMAX,YMIN,Y)                                    LAE01530
      DIMENSION Y(24)                                                   LAE01540
C                                                                       LAE01550
C.  SUBROUTINE INPUTS YCOORD. ARRAY FOR PROCESSING BY PLOT ROUTINE      LAE01560
      READ(5,900)YMAX,YMIN                                              LAE01570
      READ(5,901)Y                                                      LAE01580
C                                                                       LAE01590
C================FORMATS================                                LAE01600
900   FORMAT(2F6.2)                                                     LAE01610
901   FORMAT(12F6.2,/,12F6.2)                                           LAE01620
C=======================================                                LAE01630
C                                                                       LAE01640
      RETURN                                                            LAE01650
      END                                                               LAE01660
C                                                                       LAE01670
C                                                                       LAE01680
      FUNCTION YSCALE(YMAX,YMIN)                                        LAE01690
C.  FUNCTION GENERATES PLOTTING INCREMENT FOR A 5" AXIS                 LAE01700
      YSCALE=(YMAX-YMIN)/5.0                                            LAE01710
      RETURN                                                            LAE01720
      END                                                               LAE01730
C                                                                       LAE01740
C                                                                       LAE01750
      SUBROUTINE GRAPH(NPOINT,XCOORD,YCOORD,FVX,FVY,XINC,YINC)          LAE01760
      DIMENSION XCOORD(NPOINT),YCOORD(NPOINT),X(26),Y(26)               LAE01770
      COMMON/ISYMBL/NSYMB                                               LAE01780
C                                                                       LAE01790
C.  SUBROUTINE GRAPHS N POINTS WITHOUT ALTERING INPUT ARRAYS            LAE01800
C                                                                       LAE01810
      I1=NPOINT+1                                                       LAE01820
      I2=NPOINT+2                                                       LAE01830
C.  SET UP THE PLOTTING ARRAYS                                          LAE01840
      DO 10 I=1,NPOINT                                                  LAE01850
      X(I)=XCOORD(I)                                                    LAE01860
      Y(I)=YCOORD(I)                                                    LAE01870
10    CONTINUE                                                          LAE01880
C.  INSERT SCALING VALUES: FIRST VALUE AND AXIS INCREMENT               LAE01890
      X(I1)=FVX                                                         LAE01900
      X(I2)=XINC                                                        LAE01910
      Y(I1)=FVY                                                         LAE01920
      Y(I2)=YINC                                                        LAE01930
C.  PLOT                                                                LAE01940
      CALL LINE(X,Y,NPOINT,1,+2,NSYMB)                                  LAE01950
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C                                                                         LAE01960
      RETURN                                                              LAE01970
      END                                                                 LAE01980
C                                                                         LAE01990
C                                                                         LAE02000
      SUBROUTINE ALPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                         LAE02010
      DIMENSION CL(NCL)                                                   LAE02020
      COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,                  LAE02030
     +FCDT,DCDT,FCA,DCA,FCN,DCN                                           LAE02040
      COMMON/ISYMBL/NSYMB                                                 LAE02050
      REAL ALPHA(24)                                                      LAE02060
      DATA LMASK1/Z18FF/                                                  LAE02070
C                                                                         LAE02080
C.    SUBROUTINE PLOTS ANGLE OF ATTACK AS A FUNCTION OF LIFT COEFFICIENT  LAE02090
C.                                                                        LAE02100
C.    READ MAX,MIN ALPHA, AND ALPHA DATA                                  LAE02110
      CALL GETDAT(AMAX,AMIN,ALPHA)                                        LAE02120
C.    GENERATE SCALE DATA                                                 LAE02130
      FVALY=AMIN                                                          LAE02140
      DVY=YSCALE(AMAX,AMIN)                                               LAE02150
      FVALX=CLMIN                                                         LAE02160
      DVX=YSCALE(CLMAX,CLMIN)                                             LAE02170
      CALL NEWPEN(3)                                                      LAE02180
C.    IF 1ST ALPHA PLOT, DRAW COORDINATE AXES                             LAE02190
      IF(IFLAG.EQ.0) GO TO 10                                             LAE02200
C.    DRAW X,Y AXES                                                       LAE02210
      CALL AXIS(0.,0.,'CL',-2,5.0,0.,FVALX,DVX)                           LAE02220
      CALL AXIS(0.,0.,'ALPHA',5,5.0,90.,FVALY,DVY)                        LAE02230
C.    DRAW GRID                                                           LAE02240
      CALL NEWPEN(1)                                                      LAE02250
      CALL GRID(0.,0.,5,1.0,5,1.0,LMASK1)                                 LAE02260
C                                                                         LAE02270
C.    PLOT ALPHA                                                          LAE02280
10    CALL NEWPEN(2)                                                      LAE02290
      CALL GRAPH(NCL,CL,ALPHA,FVALX,FVALY,DVX,DVY)                        LAE02300
C                                                                         LAE02310
      RETURN                                                              LAE02320
      END                                                                 LAE02330
C                                                                         LAE02340
C                                                                         LAE02350
      SUBROUTINE CMPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                         LAE02360
      DIMENSION CL(NCL),CM(24)                                            LAE02370
      COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,                  LAE02380
     +FCDT,DCDT,FCA,DCA,FCN,DCN                                           LAE02390
      COMMON/ISYMBL/NSYMBL                                                LAE02400
      DATA LMASK1/Z18FF/                                                  LAE02410
C.                                                                        LAE02420
C.    SUBROUTINE PLOTS PITCHING COEFFICIENT AS A FUCNTION OF LIFT         LAE02430
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C.   COEFFICIENT                                                        LAE02440
C                                                                       LAE02450
C.   INPUT MAX,MIN CM AND CM DATA                                       LAE02460
        CALL GETDAT(CMMAX,CMMIN,CM)                                     LAE02470
C.   GENERATE SCALING DATA FOR PLOT: INIT.CM VAL(FCM) AND PLOT          LAE02480
C.   INCREMENT(DCM)                                                     LAE02490
        FCM=CMMIN                                                       LAE02500
        DCM=YSCALE(CMMAX,CMMIN)                                         LAE02510
C.   IF FIRST PLOT OF CM, DRAW COORDINATE AXES, OTHERWISE PROCEED       LAE02520
C.   WITH PLOTTING.                                                     LAE02530
        IF(IFLAG.EQ.0) GO TO 10                                         LAE02540
        CALL NEWPEN(3)                                                  LAE02550
        CALL AXIS(0.,0.,'CM',2,5.0,90.,FCM,DCM)                         LAE02560
C.   DRAW THE GRID                                                      LAE02570
        CALL NEWPEN(1)                                                  LAE02580
        CALL GRID(0.,0.,5,1.0,5,1.0,LMASK1)                             LAE02590
C                                                                       LAE02600
C.   PLOT CM                                                            LAE02610
10      CALL NEWPEN(2)                                                  LAE02620
        CALL GRAPH(NCL,CL,CM,FVALX,FCM,DVX,DCM)                         LAE02630
C                                                                       LAE02640
C. DONE                                                                 LAE02650
        RETURN                                                          LAE02660
        END                                                             LAE02670
C                                                                       LAE02680
C                                                                       LAE02690
        SUBROUTINE CDPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                     LAE02700
        DIMENSION CL(NCL),CD(24)                                        LAE02710
        COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,              LAE02720
       +FCDT,DCDT,FCA,DCA,FCN,DCN                                       LAE02730
        COMMON/ISYMBL/NSYMB                                             LAE02740
        DATA LMASK/Z18FF/                                               LAE02750
C                                                                       LAE02760
C.   SUBROUTINE PLOTS DRAG AS A FUCNTION OF LIFT                        LAE02770
C                                                                       LAE02780
C.   INPUT MAX,MIN CD, AND CD DATA                                      LAE02790
        CALL GETDAT(CDMAX,CDMIN,CD)                                     LAE02800
C.   GENERATE SCALE DATA: INITIAL CD (FCD), PLOT INCREMENT (DCD)        LAE02810
        FCD=CDMIN                                                       LAE02820
        DCD=YSCALE(CDMAX,CDMIN)                                         LAE02830
C.   IF 1ST PLOT OF CD, DRAW Y AXIS, OTHERWISE PROCEED                  LAE02840
C.   WITH PLOT                                                          LAE02850
        IF(IFLAG.EQ.0) GO TO 10                                         LAE02860
        CALL NEWPEN(3)                                                  LAE02870
        CALL AXIS(0.,0.,'CDI',3,5.0,90.0,FCD,DCD)                       LAE02880
C.   DRAW GRID                                                          LAE02890
        CALL NEWPEN(1)                                                  LAE02900
        CALL GRID(0.,0.,5,1.0,5,1.0,LMASK)                              LAE02910
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C.                                                                      LAE02920
C.   PLOT CD                                                            LAE02930
10      CALL NEWPEN(2)                                                  LAE02940
        CALL GRAPH(NCL,CL,CD,FVALX,FCD,DVX,DCD)                         LAE02950
C                                                                       LAE02960
C.   DONE                                                               LAE02970
        RETURN                                                          LAE02980
        END                                                             LAE02990
C                                                                       LAE03000
C                                                                       LAE03010
        SUBROUTINE CDTPLT(NCL,CL,CLMIN,CLMAX,IFLAG)                     LAE03020
        DIMENSION CL(NCL),CDT(24)                                       LAE03030
        COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,              LAE03040
      +FCDT,DCDT,FCA,DCA,FCN,DCN                                        LAE03050
        COMMON/ISYMBL/NSYMB                                             LAE03060
        DATA LMASK/Z18FF/                                               LAE03070
C.                                                                      LAE03080
C.   PLOT TOTAL DRAG AS A FUNCTION OF ANGLE OF ATTACK                   LAE03090
C                                                                       LAE03100
C.   INPUT CD DATA                                                      LAE03110
        CALL GETDAT(CDTMAX,CDTMIN,CDT)                                  LAE03120
C.   GENERATE SCALING DATA                                              LAE03130
        FCDT=CDTMIN                                                     LAE03140
        DCDT=YSCALE(CDTMAX,CDTMIN)                                      LAE03150
C.   IF 1ST PLOT DRAW Y AXIS                                            LAE03160
        IF(IFLAG.EQ.0) GO TO 10                                         LAE03170
        CALL NEWPEN(3)                                                  LAE03180
        CALL AXIS(0.,0.,'CDTOTAL',7,5.0,90.,FCDT,DCDT)                  LAE03190
        CALL AXIS(0.,0.,'CL',-2,5.0,0.0,FVALX,DVX)                      LAE03200
C.   DRAW GRID                                                          LAE03210
        CALL NEWPEN(1)                                                  LAE03220
        CALL GRID(0.,0.,5,1.0,5,1.0,LMASK)                              LAE03230
C                                                                       LAE03240
C.   PLOT CD TOTAL                                                      LAE03250
   10 CALL NEWPEN(2)                                                    LAE03260
        CALL GRAPH(NCL,CL,CDT,FVALX,FCDT,DVX,DCDT)                      LAE03270
C                                                                       LAE03280
C.   DONE                                                               LAE03290
        RETURN                                                          LAE03300
        END                                                             LAE03310
C                                                                       LAE03320
C                                                                       LAE03330
        SUBROUTINE CAPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                     LAE03340
        DIMENSION CL(NCL),CA(24)                                        LAE03350
        COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,              LAE03360
      +FCDT,DCDT,FCA,DCA,FCN,DCN                                        LAE03370
        COMMON/ISYMBL/NSYMB                                             LAE03380
        DATA LMASK/Z18FF/                                               LAE03390
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C                                                                       LAE03400
C.    PLOT CA AS A FUNCTION OF ANGLE OF ATTACK                          LAE03410
C                                                                       LAE03420
C.    INPUT CA DATA                                                     LAE03430
         CALL GETDAT(CAMAX,CAMIN,CA)                                    LAE03440
C.    GENERATE SCALE DATA                                               LAE03450
         FCA=CAMIN                                                      LAE03460
         DCA=YSCALE(CAMAX,CAMIN)                                        LAE03470
C.    IF 1ST PLOT DRAW Y AXIS                                           LAE03480
         IF(IFLAG.EQ.0) GO TO 10                                        LAE03490
         CALL NEWPEN(3)                                                 LAE03500
         CALL AXIS(0.,0.,'CA',2,5.,90.,FCA,DCA)                         LAE03510
C.    DRAW GRID                                                         LAE03520
         CALL NEWPEN(1)                                                 LAE03530
         CALL GRID(0.,0.,5,1.0,5,1.0,LMASK)                             LAE03540
C                                                                       LAE03550
C.    PLOT CA                                                           LAE03560
   10 CALL NEWPEN(2)                                                    LAE03570
         CALL GRAPH(NCL,CL,CA,FVALX,FCA,DVX,DCA)                        LAE03580
C                                                                       LAE03590
C.    DONE                                                              LAE03600
         RETURN                                                         LAE03610
         END                                                            LAE03620
C                                                                       LAE03630
C                                                                       LAE03640
         SUBROUTINE CNPLOT(NCL,CL,CLMIN,CLMAX,IFLAG)                    LAE03650
         DIMENSION CL(NCL),CN(24)                                       LAE03660
         COMMON/ASCALE/FVALX,FVALY,DVX,DVY,FCM,DCM,FCD,DCD,             LAE03670
        +FCDT,DCDT,FCA,DCA,FCN,DCN                                      LAE03680
         COMMON/ISYMBL/NSYMB                                            LAE03690
         DATA LMASK/Z18FF/                                              LAE03700
C                                                                       LAE03710
C.    PLOT NORMAL FORCE AS A FUNCTION OF ANGLE OF ATTACK                LAE03720
C.                                                                      LAE03730
C.    INPUT CN DATA                                                     LAE03740
         CALL GETDAT(CNMAX,CNMIN,CN)                                    LAE03750
C.    GENERATE SCALE DATA                                               LAE03760
         FCN=CNMIN                                                      LAE03770
         DCN=YSCALE(CNMAX,CNMIN)                                        LAE03780
C.    IF 1ST PLOT, DRAW Y AXIS                                          LAE03790
         IF(IFLAG.EQ.0) GO TO 10                                        LAE03800
         CALL NEWPEN(3)                                                 LAE03810
         CALL AXIS(0.,0.,'CN',2,5.,90.,FCN,DCN)                         LAE03820
C.    DRAW GRID                                                         LAE03830
         CALL NEWPEN(1)                                                 LAE03840
         CALL GRID(0.,0.,5,1.,5,1.,LMASK)                               LAE03850
C                                                                       LAE03860
C.    PLOT CN                                                           LAE03870
```

```
   10 CALL NEWPEN(2)                                                    LAE03880
      CALL GRAPH(NCL,CL,CN,FVALX,FCN,DVX,DCN)                           LAE03890
C                                                                       LAE03900
C.   DONE                                                               LAE03910
      RETURN                                                            LAE03920
      END                                                               LAE03930
/*                                                                      LAE03940
//GO.PLOTPARM DD *                                                      LAE03950
 &PLOT SCALE=0.85 &END                                                  LAE03960
/*                                                                      LAE03970
//GO.SYSIN DD *                                                         LAE03980
```

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